

THE
GOVERNMENT
MUSEUM
CHENNAI



Special Volume on
**Conservation of
Stone Objects**



Editor
Dr. V. Jeyaraj



Special Volume on

Conservation of Stone Objects

In Commemoration of the
150th Year Celebrations of the
Government Museum,
Chennai-600 008

Editor

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This special volume is dedicated to
the staff of the museum – the past
and the present.

-Editor

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Foreword

150 years of standing of any institution is always commendable. The Government Museum, Chennai has completed 150 years of service to the community. Having started its service in 1851, it continues to serve in the field of educating people while entertaining them. The Museum was established in 1851, but it started the Chemical Conservation Laboratory only in 1930 in order to preserve the bronze icons received through the Treasure-trove Act. It is the pioneer in this field, as this is the first State to have started conservation activities. Dr. S. Paramasivan, the first Curator of this Laboratory is known for his innovations in conservation research and got D. Sc for his innovative research by the University of Madras in 1940 itself. His service to the Archaeological Survey of India from this Laboratory was a pioneering activity.

The conservation activities of this museum were extended from bronzes to wall paintings and later to all other materials. In 1963, a separate two-storied block was constructed for the Laboratory based on the blue print of Dr. S. Paramasivan. At that time, Dr. S. T. Sanyamurti was the Director of the Museum and Mr. N. Harinarayana was the Curator of the Laboratory. Being one of the service sections of this museum, this Laboratory has contributed a lot to the proper preservation of the artefacts of this museum. Successive Curators continued to serve for the preservation of the museum antiquities as well as to conserve cultural heritage for other institutions.

The Government Museum, Chennai and the district museums in the State have more than two lakhs of antiquities and objects. Preservation is a priority activity of museums. The Chemical Conservation and Research Laboratory of the museum has done many conservation activities in the museum in an innovative manner. Many courses, programmes, workshops, seminars have been conducted by this Laboratory. It has established a Conservation Gallery to explain to the public the various procedures to be adopted for the preservation of the museum objects. It has been recognized by the University of Madras as a research institution for conducting research leading to Ph. D. Degree.

Dr. V. Jeyaraj, Curator of the Chemical Conservation and Research Laboratory of the Museum is responsible for the various conservation activities of this museum. As a milestone for the museum conducting the International Seminar on Conservation of Stone Objects with Reference to Limestone Objects during 18th - 21st December 2001. It was a collaborative programme with the Nehru Trust for Indian Collections at the Victoria and Albert Museum, New Delhi and the Indian Association for the Study of Conservation of Cultural Property, New Delhi. This was a massive effort involving the entire staff and resources of the department of museums.

The Government of Tamil Nadu have sanctioned the publication of a Special Volume of Conservation of Stone Objects based on the Seminar Proceedings. Dr. V. Jeyaraj has edited the papers and the volume is ready so that those interested in the preservation can refer to this book. I hope this will be one of the source books for Conservators, Curators, Archaeologists, Conservation Engineers etc.

Chennai - 600 008,

31.3.2003.


31/3/2003

(Dr. R. Kannan, Ph.D., I.A.S.)

Editorial

Special occasions like 150th Year Celebrations are very important to any organisation. The Government Museum, Chennai has completed 150 years of service by 2001. When one turns back and sees the past, he is able to see the milestones of activities of the museum from its inception. When the 150th Year Celebrations were planned by the Commissioner of Museums, Dr. R. Kannan, I.A.S., with the museum staff, various activities were contemplated. One among them was the conduct of an International Seminar on Conservation of Stone Objects with Special Reference to Limestone Objects during December 2001. The topic of the seminar was so named as the museum administration wanted to save the *Amaravati* limestone sculptures embedded in to the walls of the museum about 130 years ago. Besides this, during my personal discussion at New Delhi with Dr. D. A. Swallow, Executive Trustee of the Nehru Trust for the Indian Collections at the Victoria and Albert Museum at New Delhi, she showed much interest to hold an international seminar exclusively for getting suggestions to conserve the *Amaravati* limestone sculptures in the Government Museum, Chennai and came forward to help in organising a seminar with specialists from the U.K. This was the ignition point and I worked for the International Seminar and the motivation of Dr. R. Kannan, Ph.D., I.A.S., was the encouragement for me to work on the subject. Since it included *Amaravati* Sculptures, Mr. R. Balasubramanian, Curator of the Archaeology Section of the Museum, who also had gone to the UK to study the problems of the *Amaravati* sculptures in the British Museum, shouldered the responsibilities with me in the organisation of the seminar. Entire staff of the Government Museum and Curators and staff of some of the district museums involved in organising the seminar and it was a successful one. It was a collaborative venture with the Nehru Trust for the Indian Collections at the Victoria and Albert Museum at London, New Delhi, Indian Association for the Study

of Conservation of Cultural Property, New Delhi, which is a forum of professionals in the field.

It was planned ahead to bring out a Special Volume on Conservation of Stone Objects. Therefore, chosen experts in conservation from home and abroad were requested to contribute to the volume. Even though, there was enough time for the preparation of relevant papers, many of them could not send research papers on time. Therefore, in addition to the special papers received from experts in the conservation of stone objects, some of the papers presented in the international seminar also have been included in this volume.

This book has been divided in to three parts, viz. General, General Papers and Conservation Papers.

In the General part, information such as welcome address and report on the activities of the Government Museum by Dr. R. Kannan, report on the activities of the Chemical Conservation and Research Laboratory by Dr. V. Jeyaraj, Chennai, the inaugural address by the Honourable Minister for Education, Dr. M. Thambidurai, valedictory address by Dr. Baldev Raj, key note address of the seminar by Dr. M. Velayuthan Nair, briefing of the seminar proceedings by Dr. R. Kannan, I.A.S., are included.

In the General Papers Section, papers pertaining to literature relevant to stone objects, geology of stone, preservation of art and cultural heritage, role of museums in preserving stone objects, role of curators in preservation, transporting, displaying, restoring stone objects etc., authentication of stone objects, collection of stone objects in museums, laws pertaining to preservation etc., by university professors, museologists, conservators, archaeologists, anthropologists, conservators, lawyers, administrators etc., have found place.

The third part of the book contains papers on bio-deterioration, lichens on monuments and their remedy, conservation problems, conservation of monuments, retrofit measures in the earthquake

affected Gujarat State monuments, Amaravati Limestone Sculptures in the British Museum, Mughal Colonnade in the Victoria and Albert Museum, London, Conservation Measures to the Amaravati Limestone Sculptures in the Victoria and Albert Museum, papers by the Curators of the department of museums, Government of Tamil Nadu.

Along with the running text, black and white photographs relevant to the text are included enabling the readers to understand the subject well. Sixteen colour plates comprising around hundred colour photographs add aesthetics to the book.

The authors of the articles have done a good job by putting their experience in preservation as well as conservation in a capsule. I hope I have done full justification in editing the book, *Conservation of Stone Objects*. This will be a source book in the field.

Chennai - 600 008,

15.2.2005



(V. Jayaram)

Acknowledgements

The Special Volume on Conservation of Stone Objects is the result of concerted efforts of so many in the Department of Museums. I thank on behalf of the Commissioner of Museums, Mr. P.A. Ramiah, I.A.S., Secretary to Government, Tamil Development-Culture and Religious Endowments for the financial sanction to conduct the seminar. I would like to extend my gratitude to the Commissioner of Agriculture and Museums, Dr. R. Kannan, Ph. D., I.A.S., for his enthusiasm to bring out publications and his constant encouragement to bring it out at the right time. I should thank him for having organised the International Seminar on Conservation of Stone Objects with Special Reference to Limestone Objects. I thank Mr. K. Lakshminarasayan, Assistant Director for co-ordinating in the publication of the book through Mr. K. Sekar, Curator for Children's Museum. While organising the seminar, Curators of both Chennai Museum and District Museums helped a lot to make the seminar a grand success. I shall fail in my duty, if I do not thank Mr. R. Balasubramanian, Mr. J. R. Asokan and Dr. C. Maheswari in particular.

I should thank the Nehru Trust for the Indian Collections at the V&A Museum, New Delhi especially the Executive Trustee, Dr. D. A. Swallow and Secretary, Mr. R.L. Piplani for organising the British experts Dr. Robert Knox and Dr. Stephen Powles to participate in the seminar at the expenses of the Nehru Trust. I thank Dr. I. K. Bhatnagar and Mr. S. P. Singh the President and Secretary of the Indian Association for the Study of Conservation of Cultural Property (IASC) for organising the conservators to participate in the seminar in large numbers. I thank the members of IASC for electing me as the President of the IASC during the 2001 session.

The help rendered by Mr. J. D. Jagannathan, Laboratory Assistant, Mr. P. Raja Balachandran Murugan, Technical Assistant,

Mr. S. Sampath, Gallery Guard (Staff of the Laboratory), Ma. Besue Cecil, Ph. D. Research Scholar (help rendered as proof reader), Mr. S. Muthukrishnan, Photographer, Mr. S. Gurja Sankar, Assistant Photographer and Mr. G. Ramesh, Technical Assistant for helping in taking photographs. I shall fail in my duty if I do not thank the ministerial staff of the museum.

I thank the contributors of the book for sharing their experiences through their papers.

I should thank M/s. Akshara Desk Top Publishing for bringing out this book as per the approved design and layout of Mr. J. Abraham Durairaj of Hepzabah Impressions, Chennai-600 078.

Chennai-600 008,
15.2.2003

(V. Jeyan)
Editor

Welcome Address

Honourable Minister for Education, Dr. M. Thambidurai, Prof. I. K. Bhattachar, President of the Indian Association for the Study of Conservation of Cultural Property, Dr. D. A. Swallow, Executive Trustee of the Indian Collections at the Victoria and Albert Museum, London at New Delhi, Mr. S. P. Singh, Secretary, Indian Association for the Study of Conservation of Cultural Property, Secretary, Colleagues from the Government Museum, Chennai, Learned Delegates, Ladies and Gentlemen:

The Government Museum, Chennai is one of the great museums of this world. It has the second largest collection in India.

The 150th Year of this Museum is a landmark event not only in its history, but also in the world of museology. On this momentous occasion, it gives me great pleasure to welcome the scholars from all parts of the world. This is the first international seminar organised by this Museum. I feel extremely humble considering the event, the institution and the gathering.

First of all, on behalf of the Government Museum, Chennai and the institutions who have joined us in organising this event viz., the Indian Association for the Study of Conservation of Cultural Property, New Delhi and the Nehru Trust for the Indian Collections at the Victoria and Albert Museum, London at New Delhi, I extend a hearty welcome to our Honourable Minister for Education, Dr. M. Thambidurai, who has graciously consented to inaugurate this seminar, special exhibition and launch the Web Site of this Museum amidst his busy schedule. He himself is a scholar and academician. On behalf of the organisers of this Seminar, I once again extend our warm welcome to you, Sir.

The Secretary to Government, Tamil Development-culture and Religious Endowments Department, Mr. P.A. Ramiah, I.A.S., who was kind enough to agree to preside over the function, has been called on urgent duty elsewhere. He has been a source of support to this Museum.

I wish to extend a warm welcome to Dr. D.A. Swallow, Executive Trustee of the Nehru Trust for the Indian Collections at the Victoria and Albert Museum, London at New Delhi, one of the co-organisers of this seminar.

I welcome Prof. L.K. Bhattacharya and Mr. S.P. Singh, the President and the Secretary respectively of the Indian Association for the Study of Conservation of Cultural Property, for having shared our burdens in organising this international seminar. They are co-hosts as well.

I wish to warmly welcome the delegates, the dignitaries and the scholars from home and abroad who have honoured by their participation in this seminar.

I, reiterate, my warm welcome to all of you here, who have come from far and near.

Chennai-8,
18-12-2001.

Dr. R. Kannan, Ph.D., I.A.S

Report on the Activities of the Chemical Conservation and Research Laboratory

With the valuable collection at the Government Museum, Chennai, it was felt necessary to treat the bronzes disfigured by corrosive crusts in order to expose the decorative details and to eliminate the bronze disease, which brought in added deterioration. As a result of the discussion with various chemists, the electrolytic restoration of bronzes was started in the museum. The Chemical Conservation and Research Laboratory in the museum owes to the scientific vision and foresight of Dr. P. H. Gravelly, Superintendent of the Government Museum, Madras in the early 1930s. Dr. S. Paramesivan was appointed as the Chemist in 1930. He was very active both in conservation and research activities. Besides the treatment of bronze objects, ethnological, prehistoric and numismatic objects were treated. In 1935, the Government Museum, Madras was also of help to the Archaeological Survey of India in the examination of wall paintings at Tanjore, Srirangavasi etc.

In 1937, a separate Chemical Conservation Laboratory Block (Old Chemistry Block) was built, being the only one of its kind in India. A two-storied building for the Laboratory was constructed in 1963. In 1997, the Chemical Conservation and Research Laboratory was recognised as a research institution to conduct research leading to Ph. D. Degree and Dr. V. Jeyaraj, Curator of the Laboratory has been recognised as a Research Supervisor by the University of Madras. At present two part-time and two full time scholars are working under him on research projects related to conservation.

Research Activities

One of the foremost activities of the Laboratory is to conduct research in new methods of conservation and materials of the

Paramasivan, the first Curator of the Laboratory, on paintings and metallic antiquities. The research findings were published in leading scientific journals both in India and abroad. The research activities are being continued successfully by the Curators of the Laboratory till date. At present research projects such as *Fingerprinting of South Indian Bronze Icons*, *Holographing Museum Antiquities*, *Survey of Monuments in Tamil Nadu*, *Conservation of Metallic Antiquities*, *Conservation of Chola Period Coins*, *Conservation of Wall Paintings*, *Art History and Conservation of Paintings of South India*, *Conservation of Indian Traditional Textiles* etc., are under progress.

The Laboratory is interested in the conservation research in order to find out new techniques and materials in collaboration with leading research institutions such as Indira Gandhi Centre for Atomic Research, Kalpakkam; Indian Institute of Technology, Chennai; Anna University, Environmental Engineering Wing of the CSIR, Chennai etc.

Publications

The publication of this Laboratory from its inception is commendable. Leading national and international journals such as Indian Academy of Sciences, The Current Science, Conservation of Cultural Property in India, Technical Studies, Studies in Conservation etc., published the out come of the research works. Besides hundreds of research and popular articles, many books and bulletins have been published. Handbook on Conservation in Museums, Care of Museum Objects, Conservation of Archival Materials, An Introduction to the Chemical Conservation and Research Laboratory, Care of Records, Conservation of Temple Objects, Conservation of Cultural Property in India, Restored Paintings from Madras Christian College, Conservation of Cultural Heritage, Metal Conservation etc., are some of its publications. Many conservation reports have been prepared by the successive curators regularly through out the career of this Laboratory. Dr. V. Jeyaraj, the present Curator has prepared thirty-five reports.

Training

In order to disseminate the expertise of the Laboratory, a refresher course on *Care of Museum Objects* was started in 1974. It was well received by professionals in this field and students of museum related subjects. In 1993, a course on *Care of Temple Architecture* was conducted for the Executive Officers of the Hindu Religious and Charitable Endowments Department. In 1997, a course on *Care of Ancient Materials* was conducted exclusively for the Archivists. Students from the College of Fine Arts were given project training for a period of 3 months on conservation of museum objects especially paintings. Later, this course was named as the course on *Care of Art Objects*. Besides these, training programmes are given to school and college students both in Chennai and other districts on *Care of Cultural Materials and Preservation of Monuments*. It has entered its name as the number one in the field by introducing *Internship Training* for a period of one year. Recently a series of capsule courses on *Conservation of Cultural Heritage* were conducted at Chennai, Trichy, Salem and Madurai for officials of departments such as Museums, Archaeology, Police, Hindu Religious and Charitable Endowments and Southern Railway to create awareness on *Conservation of Cultural Heritage*.

Conservation Consultancy Services

Even though the strength of the staff in the Laboratory is inadequate, the Laboratory has extended service to the public and other institutions interested in the preservation of objects of the past at nominal charges. It has extended conservation services to various temples under the Hindu Religious and Charitable Endowments Department, Churches like St. George's Cathedral Church, St. Andrews Church, religious institutions like Ramanashram, Mahatma Ram Sathi Kumar, Therotharamada, College of Fine Arts, Raj Bhavan, Government Eye Hospital, Madras Medical College, Government Royapettah Hospital, Madras Christian College and a number of private institutions

Report on the Activities of the Chemical Conservation and Research Laboratory



Opening of the Chemical Conservation Laboratory
by His Excellency Mr. Balarama Mehta,
Governor of Tamil Nadu,
Mr. N. Hanumanthrao, Curator and
Dr. S. T. Rayamurthy, Director look on (1963)



Dr. G.P. Agrawal, Dr. V. Jayaram, Dr. S. Parmanandam,
Mr. N. Hanumanthrao and Mr. G. Rameshram with the
then Honorable Minister, Mr. K. Rajagopal during the
Golden Jubilee Celebrations of the Laboratory (1981)



Workshop on Conservation of Paintings (2001)



Training on Care of Museum Objects (2006)



Training to the Officers of the Hindu
Religious and Charitable Endowments Department
on Care of Temple Antiquities (2006)



Training to the Officers of the Andhra
on Care of Ancient Manuscripts (1996)

Report on the Activities of the Chemical Conservation and Research Laboratory



A View of the Conservation Gallery in 1999, 2001, 2003 respectively



Release of a Book on Conservation of
Thangtara Paintings in Madurai (2002)



Restoration of Thangtara Paintings and Workshop
on Thangtara Paintings in Madurai (2002)



Review of Popular Lectures (1997)



Exhibition on Finger Printing of Brasses During
the Silver Jubilee Celebrations of the Centre at
Coir of Museum Chennai (1997)

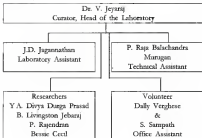
and individuals. The Laboratory is not able to meet the requirements of the museum as well as the outside demand due to want of staff in the Laboratory. On request the Curator delivers lectures on conservation in various media and in various institutions in order to popularise the subject.

Conservation Gallery

The Chemical Conservation and Research Laboratory of the Chennai Museum has set up the Conservation Gallery in order to educate the visitors on the preservation of the cultural and artistic heritage of our country. It was refurbished recently. This Laboratory is pioneer in this respect.

Staff

The Chennai Museum is a multipurpose museum having over one-lakh objects and about 5% of them are in need of conservation treatment. But the strength of the staff is inadequate. At present only four members of staff man the Laboratory. One volunteer, four researchers are helping in the activities of the Laboratory.



Milestones of the Chemical Conservation and Research Laboratory

- 1930 Establishment of the Conservation Laboratory - Appointment of Dr. S. Paramasivan the first Curator to the Laboratory.
- 1931 Installation of motor generator for electrolytic restoration for the first time in India.
- 1934 Preservation and x-ray studies of Nagpatthanas bronzes.
- 1935 Preliminary report on the mural paintings in the Brhadiswara temple at Tanjore (June - July 1935).
- 1937 Study and preservation of wall paintings at *Ishtambal*.
- 1938 Studies of the techniques of wall paintings in fifteen well-known sites.
- 1939 Systematic study of the metallography of bronze objects and prehistoric implements.
- 1944 Examination of *Marathi* paintings in the Tanjore Palace and the *Chola* paintings in Brhadiswara temple at Tanjore.
- 1946 Mr. B. Narayana Shenoy was appointed as curator.
- 1949 Mr. R. Subramanian was appointed as curator.
- 1952 Experiments in museum climate in the National Art Gallery and the main Museum building, experiments in the use of latex for taking moulds of image and coins.
- 1953 Experiments in the use of Asiatic seaweed for preparing moulds.
- 1954 Research in the treatment of metal objects in the John Hopkins University by R. Subramanian.
Special exhibition on "Glass"
Mr. N. Hannarayana was appointed as curator.
- 1956 Mr. B. Ramachandran was appointed as curator.
- 1961 Special exhibition on "Electrolytic Treatment of Bronze Images".

- 1962 Preparation of three reports on "Museum Objects in Humid and Hot Climates", "Electrolytic Restoration of Metals" and "Study of Stones" for ICOM Committees.
- 1963 Report on the Preservation of Bronzes in the Tanjore Art Gallery.
- 1965 Mr. S. Thangavelu was appointed as curator.
- 1972 Preservation of Paintings in the *Vrajjapala* Shrine in the temple at *Jirangam*.
- 1973 Preservation of Marbles in the St. George's Cathedral Church, Madras.
- 1973 Preservation of Oil Paintings in the Rajaji Hall, Madras.
- 1973 Preparation of report on Conservation of Museum Objects in the Pudukkottai Museum.
- 1974 Examination of Ancient Pottery Specimens for the Department of Archaeology, University of Madras.
- 1974 Report on preservation of newspapers in the *Sandamantam* office.
Special exhibition on "Conservation of Iron Objects".
Examination of paintings around the Golden Lily Tank in the *Arudaya Moorthy-Sandamantam* temple in Madurai.
Starting the Course "Care of Museum Objects".
- 1975 Preservation of *Talipakkam Annamacharya* copper plates of the *Tirupati Tirumala Devasthanam*, Tirupati.
- 1975 Examination of a temple car at *Nalagudi* near Pudukkottai and report on its conservation.
- 1975 Examination of paintings in *San Varadaguruvary* temple in *Kanchipuram* and report on their conservation.
- 1975 Examination of salt - encrusted pillars in the temple at *Thiruvallur* and report of suggested treatment sent to the temple authorities.
- 1976 Experiments on analysis of three small metal objects through the use of isotope-excited x-ray fluorescence in the Bhabha Atomic Research Centre, Bombay.

- 1976 Preservation of British prints of the Raj Bhavan, Madras
- 1977 Preservation of marble statues and tablets in the St. Andrew's Church, Egmore
- 1978 Mr. V. Jeyaraj joined as the Curator, Chemical Conservation and Research Laboratory.
A Special Exhibition on Conservation of Paper Prints
- 1979 Preservation of Oil Paintings in the Madras Medical College, Madras.
- 1982 Treatment of Duplex Statue, Pondicherry.
- 1982 A Laboratory Assistant post was created and filled.
Golden Jubilee of the Laboratory was celebrated.
"Conservation of Textiles" - All India Seminar conducted along with an Exhibition on Conservation of Textiles.
- 1983 Restoration of Marble Sculptures and Tablets at St George's Cathedral, Chennai.
Curator, V. Jeyaraj, registered for his Ph.D. Degree
- 1984 Treating a large *Vishnu* stone statue at CIPET, Chennai
- 1985 Setting up of Micro-analytical Corner in the Laboratory.
- 1986 Conducted a Conservation Course for Madurai University M.A. (History of Art) students.
- 1987 Treatment to the Tanjore Art Gallery Bronzes.
- 1988 Workshop on "Conservation of Textiles"
Treatment of old records at Simpson Company, Chennai.
- 1989 Treatment of paper prints and oil paintings at Raj Bhavan, Chennai.
- 1990 Ph.D. Degree was awarded to V. Jeyaraj for thesis on "Correlation between Composition, Corrosion Products and Metallographic Structure of Metallic Antiquaries" by the University of Madras.
Treatment of palm-leaf manuscripts at *Vidhya Pradam*, Sholinghur.

- 1991 Workshop on "Conservation of Paintings" in collaboration with National Research Laboratory for Conservation, Lucknow.
- 1992 Treatment of 500 Chola bronzes for the Exhibition "South Indian Bronzes".
- 1993 N.S.S. Special Camp-Preservation of Our Heritage
Award of U.K. Visiting Fellowship to Dr.V. Jeyaraj by the Nehru Trust, New Delhi.
- 1995 Course on "Care of Temple Antiquities" for Temple Executive Officers
Books such as Handbook on Conservation in Museums, by Dr.V. Jeyaraj Care of Museum Objects jointly edited with Mr.N.Hannarayana was published.
- 1996 Course on "Care of Archival Materials" for archivists
The Laboratory was recognised as a Research Laboratory to conduct research leading to Ph.D. Degree by the University of Madras, Chennai.
Report on Technical Study of Coins of Arcot Nawabs.
- 1997 Dr.V. Jeyaraj was recognised as a Guide to supervise the work of Ph.D. Scholars by the University of Madras.
Joint project on Finger Printing of South Indian Bronzes with the Indira Gandhi Centre for Atomic Research, Kalpakkam was started.
- 1998 Dr.V. Jeyaraj received a research grant from the Nehru Trust for the Indian Collections at the Victoria and Albert Museum for the study on "Directory of Museums and Galleries in Tamil Nadu"
- 1999 Conducted the Silver Jubilee Celebrations of the Course on Care of Museum Objects.
Oratorical competition and exhibition on Conservation of Museum Objects were conducted. One-day seminar on Conservation of Cultural Property was conducted and the

proceedings of the seminar was brought out in the form of a book.

Books by Dr.V. Jeyaraj on *Care of Archival Materials and Care of Temple Antiquities (Tamil)* were published by the *Jayarasi Mahal Library, Thanjavur*.

Dr.V. Jeyaraj, Curator of the Laboratory was elected as the Vice-President of the Indian Association for the Study of Conservation of Cultural Property, New Delhi, which is a professional body of Conservators.

Awarded a Small Study and Research Grant from the Nehru Trust for the collections at the V&A Museum "Directory of Monuments in Tamil Nadu".

Mr.B.Livingstone Jeyaraj, a part-time research scholar registered his name in the University of Madras under Dr.V. Jeyaraj, Curator of the Laboratory to undertake research in Conservation of Chola Coins.

2000 Dr.V. Jeyaraj was awarded the Getty Travel Award to participate in the IIC Conference in Melbourne, Australia.

2001 Seminar on "Protection of Cultural Property" under the auspices of the inauguration of the District Museum at Virudhunagar.

International Seminar on Conservation of Stone Objects with Special Reference to Limestone Objects.

Exhibition on Conservation of Stone Objects was conducted.

Publication of a pamphlet on the Exhibition on Conservation of Stone Objects and the release of the Abstracts Book of the International Seminar were made.

Mr.A.Rajendran, a part-time research scholar on Conservation of Wall Paintings and Ms.Y.A. Divya Durga Prasad, a full time research scholar on Conservation of Paintings registered their names in the University of Madras for Ph.D. under Dr.V. Jeyaraj.

Dr.V. Jeyaraj, Curator of the Laboratory was elected as the President of the Indian Association for the Study of Conservation of Cultural Property, New Delhi.

- 2002 Report on Conservation of Wall Paintings at the Thanganga temple, Thiruvavar was prepared. Reprinted the three conservation books already authored by Dr.V. Jeyaraj and authored a book on Care of Paintings.

Conservation of two large sized Thanjavur Panel Paintings at *Arudanga Minakshi Sundareswarar Temple, Madurai*.

Workshop on Conservation of Panel Paintings at Madurai for two weeks was conducted.

A booklet on Conservation of Thanjavur Panel Paintings (Tamil) was published.

Capsule Courses on Conservation of Cultural Heritage at Chennai, Thiruchirappalli, Salem and Madurai for Curators, Archaeologists, Epigraphists, Executive Officers etc. were conducted.

Conducted an International Workshop on Metal Conservation in collaboration with conservation of Cultural Property, Lucknow. An exhibition on Conservation of Museum Objects with special Reference to the Conservation of Metal Objects was conducted.

A brochure on the Exhibition on Conservation of Museum Objects with Special Reference to the Metal Objects was published.

A monograph on Metal Conservation by Dr.V. Jeyaraj was published.

Ms.Bessie Cecil, research scholar joined the Laboratory for conducting research leading to Ph.D. Degree under the guidance of Dr.V. Jeyaraj.

— Dr.V. Jeyaraj

Report on the Activities of the Museum

Report about the 150th Year Celebrations and Activities of the Museum delivered by Dr.R. Kannan, I.A.S., Commissioner of Archaeology and Museums, Government of Tamil Nadu at the Inaugural Function of the 'International Seminar on Conservation of Stone Objects with Special Reference to Limestone Objects' held at the Government Museum, Chennai on 18.12.2001.

The Government Museum, Chennai was started in 1851 A.D. Surgeon General Edward Green Balfour who assumed his position as the first Officer-in-charge of this Museum began his work by organising the geological collections of Madras Literary Society into the Madras Central Museum. It is interesting to note that it was the chief medical professionals, who were in charge of this museum for quite a long time. May be their interests were eclectic, a far cry from the world of specialists of today. Captain J. Mitchell, Surgeon G.Bodie, Dr. E. Thurston, Dr. J.R. Henderson, Dr. F.H. Gravely succeeded E.Balfour as the Superintendents of this Museum. There is still a road called Balfour Road in Kelys in Chennai. The full time Superintendents started with Dr.Thurston. They live on by their books. For example, *The Castes and Tribes of South India* is still a reference work for anybody who wants to refer to anything in this field. Dr. A. Aiyappan became the first Indian Superintendent of the Museum. In this Museum several world-renowned Indian personalities like Dr. C. Sriramamurthy, Dr. S. Paramasivan have also served in the capacity of Curators and made memorable contributions in their respective fields.

As time passed the Chennai Museum, which started to function with a mere display of geological exhibits, expanded its activities with acquisition of materials both chronologically and geographically. Consequently, it became a full-fledged

multi-disciplinary museum having several collection sections belonging to the disciplines Anthropology, Archaeology, Art, Numismatics, Botany, Zoology and Geology Sections. In addition to these sections, a separate Chemical Conservation Section to deal with the conservation activities was also added in 1930. The Philately Section was started in 1960. An exclusive Children's Museum was carved out, during 1980s, from an already existed Children's Section, by modernising and reorganising it.

The museum was the Central Museum for Madras Presidency in the days of the British Raj and then Composite Madras State. This geographic area comprised virtually the whole of South India and extended up to large parts of Orissa till Cuttack. It continues to be the premier museum for South India, being the second largest in the country with its collection of nearly two hundred thousand objects.

During 1951 A.D., the Chennai Museum celebrated its Centenary in a fitting manner, with a series of activities such as 'Special Exhibitions', 'Release of a Centenary Souvenir', a 'Centenary Celebration' attended and inaugurated by our first Indian Prime Minister, Pandit Jawaharlal Nehru. On a personal note, I must state here that my grandfather, who was an Engineer in the Public Works Department, was associated with this work, which has been graciously acknowledged by Dr. A. Aiyappan by name in the Centenary Souvenir.

The history up to 1951 A.D. has been documented in the Centenary Souvenir.

Since 1951 A.D., the following important events have taken place:

1. In 1963, the galleries of Systematic Botany, Mammal, Invertebrate, Industrial Art were modernised on a large scale. Further, the exhibits of the National Art Gallery were given a face-lift in the same period.
2. In 1984, the Contemporary Art Gallery was inaugurated with an exclusive building being built for it.

3. The Children's Section of this Museum was reorganised into a separate Children's Museum and inaugurated in 1988.
4. During January 1990, an All India Museum Camp was organised in the Museum, which was attended by museologists drawn from all over the country.
5. In 1992, the Museum Theatre was air-conditioned for better comfort.
6. King Burender and Queen Aishwarya of Nepal visited this Museum on 9.5.1993. A Special Exhibition on the focal theme 'South Indian Bronzes' was organised on 14th April, 1994. The Chief Minister, Dr. J. Jayalithaa inaugurated the exhibition and released a Special Postal Cancellation Cover of National Art Gallery.
7. The systematic publication of the Journal to fill up the void caused by the cessation of publication of the Museum Administration Reports since 1978 A.D., was started in 1996 A.D.
8. There was revival of the Popular Lecture Series in 1999 A.D. with eminent scholars from India and abroad delivering the lectures.
9. Outreach activities like restoration of portraits for the Madras Medical College of the Surgeons-General of yester years and similar restoration of portraits of the erstwhile Principals of the Madras Christian College, nine training workshops for the citizens of Tamilnadu in traditional paintings of various parts of India like Madhubani etc., participation in exhibitions like the Platinum Jubilee Celebrations of Loyola College, Chennai are some that readily spring to the mind.
10. A filip was given to new publications and reprinting of old publications which had gone out of print from 1999 A.D. onwards. Private sponsorship by a famous company that used to transport Brinsforders from the early 19th Century A.D. onwards of the title Jain Images in the Government

Museum, Chennai' published in 2001 A.D., brought this museum in line with the national policy and current international practice of attracting sponsorships to make museums self-sustaining.

11. Finger Printing of Bronzes in collaboration with the Indra Gandhi Centre for Atomic Research, Kalpakkam was done on the museum bronzes.
12. In 2000 A.D., for the first time in this country, there was repatriation of art objects. The Australian High Commissioner handed the Brough Memorial Collection back to India to the then Secretary to Government, Mr. S.Ramakrishnan I.A.S.
13. Work on the holographic gallery in collaboration with Anna University was started in 2000 A.D.
14. New technology for lighting was introduced in 2001 A.D. in the Contemporary and National Art Galleries by way of Fibre Optic and Dichroic Halogen Lamps to reduce ultra violet and infra-red radiation and also reduce the lux levels to the internationally accepted levels of between 40-70 lux. These minimise deterioration and are technology demonstrators for museums in India.
15. Visual Storage on the British Museum pattern of the paintings in the Contemporary Art Gallery was introduced. These were a first for Indian museums at the time.
16. Sanitation is usually a neglected area. To cater to the international visitors, modern lavatories have been constructed. It is proposed to entrust the maintenance to an NGO in the interest of proper upkeep.
17. A Disaster Management Plan, a first for Indian museums was prepared in 2001. Training was also imparted to all personnel. This resulted in saving the heritage museum theatre from certain destruction when a fire took place on 20th December, 2000 A.D.

18. The Tanjore Art Gallery has been brought under the control of the Department of Museums vide G.O. No. Ms.244, Tamil Development-Culture, Hindu Religious and Charitable Endowments Department dated 9-10-2001.
19. The Departments of Archaeology and Museums whose work is inter-related have been brought under the control of the same Commissioner for the first time vide G.O. No. Ms.258, Tamil Development-Culture, Hindu Religious and Charitable Endowments Department dated 1-10-2001.
20. So far twenty district museums have been established at Pudukkottai, Salem, Madurai, Tiruchirappalli, Vellore, Cuddalore, Erode, Uthagamandalam, Coimbatore, Kanyakumari, Tirunelveli, Krishnagiri, Srivilliputhur, Tiruvannamalai, Nagapattinam, Kancheepuram, Karur, Ramanathapuram and Virudhunagar.

On the lines of the Centenary Celebrations, in this year 2001 A.D., it is planned to hold the 150th Year Celebrations of the Museum. Accordingly, several activities have been planned. An International Seminar on the focal theme of 'Conservation of Stone Objects with Special Reference to Limestone Objects' being inaugurated today forms the curtain raiser of all the programmes proposed for the 150th Year Celebrations.

Launching of the Web Site of the Museum with two domain names, www.chennai.museum.org and www.govtmuseumchennai.org (with photographs, virtual tour, slide show and video clippings) will be another programme of the celebrations. A 'Thematic Special Exhibition on Chola Iconography' is planned for January or February, 2002. A 'New Gallery on Rock Art' will be inaugurated during the end of March, 2002 as part of the 150th Year Celebrations. The Holographic Gallery will hopefully be ready before April 2002 subject to Anna University delivering the holograms.

The Government Museum, Chennai has been at the forefront of museology. The *Anuradha* collection of Buddhist artefacts, the

Chola and other bronze collections here, the *Bharatpala* casket, the *Rareta* stone of India holding the key to deciphering South Indian Scripts, Jain, Hindu and Buddhist images are all some of the extent of the rare artefacts here.

In painting, the works of Raja Ravi Varma, Jaimini Roy and other contemporary artists are displayed here. D.P. Roy Chowdhury's sculptures deserve special mention. In sciences, the Baleen Whale washed ashore in 1874 A.D. is considered one of the best preserved specimens in the world. There are collections of marine *amphioxus*, *arrypoda* etc. from Korusalai islands, which are wide and varied. In fact, when the American Natural History Museum wanted to do a research on 'two indigenous species of spiders (*Pseclotharia regalis* and *Pseclotharia metulica*) acquired from Vepery and Egmore, Chennai, the official came here all the way from America to start the research since some specimens of these species preserved there have disappeared. The only preserved specimens are in this museum.

The endemic collections of flora recorded in one of our ancient *Sageer* literature, viz. '*Kangai Paattu*' is also on display in this Museum. The teak tree ring gifted by the Maharaja of Travancore displays Dendrochronology is a noteworthy piece. Of the geological collections, the fossilised, articulated skeleton of rhinoceros in a well-preserved condition acquired from *Lathakulam* in Tirunelveli District of Tamil Nadu merit special mention. The Pallavuram hand axe identified by Robert Bruce Foote, earning the names 'Madrasian Hand Axe' and 'Madras Stone Tool Industry', terracotta sarcophagi of Perumbalur, Ram sarcophagus of *Sankarapuram* in Andhra Pradesh, megalithic bronze and iron implements acquired from *Adirbasaller*, the Nilgiris, Roman antiquities from *Arakkamala*, the Menah sacrificial post from *Khandam* of erstwhile Ganjam Agency tracts, the only volumes speaking of the then cultural custom of human sacrifice in British India are other unique exhibits of the Museum. It has also pioneered technology in conservation. The electrolytic

treatment of bronzes pioneered in India by Dr. S. Paramasivan was the best technology in the world at that point of time.

Technologically, also the museum continues to adopt latest technology as was done by Dr. S. Paramasivan. Fibre Optic and Dichroic Halogen lighting to display paintings installed in 2001 A.D. in order to minimise deterioration are technology demonstrators for museums in India.

The Web Site itself is a technology leap for this Museum. It has also served to document and expose the great collection for worldwide viewing. The crafting and creating of the Museum Web Site is another landmark achieved by the Museum recently. This site is one of the biggest in the world of museums, created after great toil. Many creative ideas were also generated in the process. It consists of 1400 pages of A-4 size corresponding to 122 Megabytes of electronic size. There are 52 files less than 250 Kilobytes, 15 files between 250-300 Kilobytes and 118 files of size greater than 200 Kilobytes, the total number of files being 185 in HTML format. In addition, there are VRML files for the Virtual Tour of the Bronze Gallery, Slide Show and Video Clips. The clips have been provided in two bandwidths – low for Indian viewers with ordinary telephone line connections of usually 33 KBPS capacity though the modems are usually 56 KBPS and high for ISDN Indian viewers and foreign viewers whose bandwidth goes up to 2 MBPS and more.

The new Rock and Cave Art Gallery on the arid is being taken up after thorough research by undertaking painstaking field trips to highly inaccessible rock shelters such as Vellankombai and Idnham in the Nilgiris by the Curators and the Commissioners. The lives of the Curators and the staff were in peril at certain points of the trip.

An old museum poses its own challenges. Some of the displays are a century old. They were the best technology at the time of installation. This was because of the close ties between this museum and the museums in England. This historical link was

because the personnel were English. This link is growing weak, as Indians have fully taken over. This has to be strengthened with more visits to England and other developed countries by the museum personnel here. Still we have not given up. Frameless magazine showcases with modern lighting on par with European standards are being planned for reorganising the old galleries. A Touch Screen display, a simulated cave with infra-red ray activated *son-et-lumière* etc., are planned for the Rock and Cave Art Gallery. The Amaravati limestone sculptures, a few of which at the ground level are deteriorating due to saline action as they have been embedded in the walls for the last 130 years are being removed from the walls. They have started absorbing moisture by osmosis due to rise in road levels. They will be redisplayed accordingly to modern methods.

The single thread of thought that runs through this Medium Term Planning exercise is what started as the Mission Statement of the Museum in 1999. It was amplified as the analysis of the structure and activities of the museum from a management perspective. This analysis was debated first as a Popular Monthly Lecture delivered on 25-2-2000 and agreed. It also appeared as an article in the issue of this Journal for the period October 1999 to March 2000. It is this vision of a few Core personnel backed by a lot of resources by way of capital outlay and use of the latest technology for conserving and restoring the old heritage buildings, electronic data processing and recording of images and modernising display that is being implemented. This costs more than the usual old techniques. Like the West, it is better to have a few excellent state of the art galleries in the museum rather than have a large quantity of Second Best.

This museum is fully funded by the Government of Tamilnada. It is their generous funding that has made the development that I have adumbrated above possible. Private funding has yet to catch on.

I would like to conclude that every great institution has its periods of waxing and waning. This museum is no exception. I must thank all those who have made this journey possible. I am sure this museum will reinvent itself every few years and continue to serve the people of Chennai, Tamilnadu, India and the world. We have a long journey ahead. We pause and look at what we have achieved but we must press on.

The following lines of the poet Robert Frost so dear to Pandit Nehru, who inaugurated the Centenary celebration captures the essence I feel.

'The woods are lovely dark and deep, but I have miles to go before I sleep'.

— Dr. R. Kannan

Inaugural Address

Inaugural Address of the Honourable Minister for Education, Dr. M. Thambidurai at 11.00 hours on 18th December 2001 on the occasion of the Inauguration of the International Seminar on Conservation of Stone Objects with Special Reference to Limestone Objects.

Ladies and Gentlemen,

Let me tell first that I am indeed very happy to inaugurate the seminar. I congratulate the museum authorities for having organised for the first time in the history of the museum an International Seminar on the occasion of the 150th Year Celebrations of this museum. The International Seminar is a part of the 150th year celebrations.

This museum was established in 1851. Dr. Edward Green Balfour, the first Officer-in-charge of the museum initiated the organization of a central museum by arranging the geological specimens of the Madras Literature Society. During the Centenary Celebrations of the museum in 1951, Pandit Jawaharlal Nehru, the First Prime Minister of India dedicated the Victoria Memorial Hall in the museum campus as the National Art Gallery to the nation.

Similar to the Centenary Celebrations, the 150th year Celebrations have been planned to conduct various programmes.

The aim of the museum is to throw open to the public to derive benefit by seeing the cultural objects antiquities while preserving them for posterity. There fore, preservation for presentation is the primary activity of any museum. By understanding this well, a self sufficient Chemical Conservation and Research Laboratory was established in this museum in 1930 itself. Since then this Laboratory continues to conserve antiquities both inside and outside the museum. The First Curator of the Laboratory, Dr. S. Paramasivan introduced the Electrolytic Restoration in this

country for the conservation of bronze icons. Dr. C. Sivaramamurthi, Archaeology Curator of this museum got the credit as the First Indian Director of the National Museum, New Delhi.

The cultural objects in a museum may be organic, in-organic or a complex one. Even though stone objects such as sculptures, stone inscriptions, rocks, minerals, stone implements etc., are believed to be stable and are not affected, actually they also succumbed to various types of deterioration. Different soft stone objects such as soapstone, sandstone etc., very easily got affected. Therefore, Conservation of Stone Objects with Special Reference to Limestone Objects is the topic chosen for the seminar. Relief limestone sculptures depicting the *Jataka* stories from Amaravati belonging to 2nd Century B.C. have been embedded in to the walls of this museum. Due to the rise of the ground level, water is absorbed by sculptures embedded in to the lower level of the wall by capillary action and the sculptures are damaged. These damaged sculptures will be safely removed and subjected to conservation treatment. When we consider that they were embedded in to the wall 150 years ago, this effort of the planned conservation activity is a determined and pioneering step taken to preserve these sculptures for posterity. Today when we have lost the Barman Buddha sculptures, it is the best service of this museum to the human kind to preserve the priceless Amaravati sculptures and this is our duty to take action to conserve them.

I would like to share with you that this museum has got with it the high priced Buddha and Buddhist sculptures from Gandhara, which is called as Khandhara in history and Peshawar. These were brought when the British ruled India. They are being preserved with delicacy and utmost care.

I earnestly believe that this International Seminar will resolve in a large way the various conservation problems so far posed by stone objects especially limestone objects. I also believe that the scholars from various countries will be able to tell to the world

what scientific facts from what they have collected in this aspect. I strongly tell that the research papers on conservation of stone objects with special reference to limestone objects will not only create a new scientific arena but also will be helpful in conserving the stone sculptures in museums and other related institutions.

I am very happy to learn that, this museum has created a 1400 page web site with virtual tour, video clips etc., in the age of globalisation. This will enable any body from any part of the world to see the important exhibits with details.

I wish the International seminar a grand success and I am very happy to inaugurate the seminar, special exhibition, web site etc.

Chennai-600 008,
18.12.2001.

Dr. M. Thambidura

Key Note Address**International Seminar on Conservation of Stone Objects**

M. Velayudhan Nair,
Director of Archaeology, Kerala

Stone in its varied dimensions forms an important part of our cultural heritage, as stones are used universally for the construction of monuments, artifacts, canvas for early inscriptions, sculptures etc. At present their existence also is threatened by such universal phenomena like pollution, urbanisation, weathering and other man made and natural phenomena. The factors that affect the deterioration of stone are similar, which includes its composition, structure, surface condition, microclimate and environment. With the advancement of science and scientific techniques though several methods emerged for tackling the conservation problems of stone, solutions to several puzzles are remaining. It is a contradiction that though stone is considered to be most stable and durable material by experience, it is this material, which is most vulnerable to weathering and has posed most serious threat to conservators. Stone as cultural property can be in two forms. Stones as building material and as stored in-house as museum pieces, decorative material etc. The former presents more serious problems due to its exposure to such forces as geophysical loads from wind, temperature variations, gravity loads from vibrational load caused from vehicular traffic. To understand the mechanism of deterioration and possible control, it is essential to know the material and the problems faced by them.

Building and Monument Stones

From time immemorial, geological availability of materials has been the principal factor affecting the techniques of construction of monumental buildings and decorative sculptures. Almost all

important cultures whether it is ancient or new have a special relationship with building stone. The stone used includes all original rock that is mined or quarried and used for construction and has varied considerably from one place to another.

The geological definition of stone is based on its chemistry, fabric and mineralogy, which attributes to its origin and basic properties. Rocks are divided into the following genetic groups:

1. Sedimentary rocks, eg.: limestone, sandstone
2. Igneous rocks, eg.: granite
3. Metamorphic rocks, eg.: marble and slate.

Sedimentary

Limestone: Composed principally of calcium carbonate (calcite) or double carbonate of calcium and magnesium (dolomite). Easy adaptability of limestone makes it a favoured stone for artists. The textures vary greatly from uniform grain size and colour to a cemented shell mass. It is seen that all limestone including those of low porosity have relatively high intrinsic and micro crack and bedding permeability and are susceptible to penetrating water and gases.

Sandstone: Sandstone is consolidated sand in which the grains are composed chiefly of quartz and feldspars of fragmental texture and with various interstitial cementing materials including silica, iron oxides, calcite or clay. Enough voids generally remain in the rock to give it considerable permeability and porosity.

Igneous Rocks

Granite: Granites include almost all rocks of igneous origin. Granites are alkali feldspars and quartz with varying amounts of other minerals such as mica and hornblende in an interlocking and granular texture. They are dense with porosity and permeability low with high resistance to corrosion and weathering.

Rhyolite and Andesite : Volcanic rocks are poorly consolidated but are easy to work and have good standing strength.

Weathering of Stone

The weathering of stone is caused by the disintegration and decomposition of stone materials resulting in the formation of a veneer that differs the original material in composition and texture, the physical, chemical and biological reactions of carbonates, silicates, sulphates, oxides etc., with water and atmospheric gases resulting in the formation of clay minerals and iron and aluminium oxyhydroxides. This process is termed hydrolysis. In addition to this oxidation of ferrous iron to ferric and carbonation reactions take place.

These actions couple with low exchange and physical and biological alteration results in a marked change immediately below the stone - atmosphere interface. Surface layers are rendered less stable by progressive bond rupture, the removal of alkali and alkaline earth elements and by the resultant alterations in the structural framework of the stone.

Scientists have proposed the following different modules for the decomposition of silicate rich stones:

- a. Straight forward dissolution of the material with the solubility controlled by the concentration of silica and alumina
- b. The production of a leached layer by the exchange of cations upward and through the interior of grains in addition to solution at the interface
- c. Production of amorphous precipitate rich in aluminium and silicon that is rate controlled and dependent on pH and
- d. Production of a crystalline phase dependent on solution composition and parent solid

Deterioration of Stone Due to Air Pollution

The primary air pollution causing damage to stone is the formation of sulphur compounds such as sulphur dioxide. They originate from combustion sources, burning coal or residual oil. Deterioration of carbonate rock due to sulphur compounds is

very significant. The silicate-based rocks are typically far more resistant to weathering in urban climates. The reaction between gaseous sulphur dioxide and calcium carbonate is regarded as a two-step process:



Wet deposition involves the neutralisation of sulphuric acid found in the precipitation:



The reaction between sulphates in particulate matter deposited on the surface and the calcium carbonate is also possible. This chemical reaction results in a combination of physical changes that disrupt the surface. Finally, the surface is removed by erosion or washed off in precipitation runoff, either in solution or as suspended solids. The ultimate effect of attack by air pollution on stone is either the accelerated rate of surface loss or, in protected situations, the buildup of a crust of alteration products.

The physical changes associated with air pollution / stone interactions can be viewed as a transition between the deposition and the removal processes. The physical effects begin as deposition takes place, but the changes may continue after deposition ceases. On the molecular level, the transformation of calcite to anhydrite results in major changes in crystal lattice structure. The over all process whereby atmospheric pollutants are delivered to a stone surface forms reactive species, attack the surface and ultimately are responsible for loss of surface material.

Alteration of Carbonate Rocks

The alteration of carbonate rocks is brought about by solution due to the action of rain water directly at the surface and especially, circulating underground. This action is enhanced by the presence of carbonic acid or other acids. The rate of this process

of solution depends in particular, on the permeability of the rock, the amount of water circulating and its carbonic acid content.

At least for the great majority of a monument's surfaces, which are somewhat protected, the climate that weathers them is different from the true climate of the region where they are found in particular regarding one of the fundamental factors that define a climate: the annual rainfall per unit of surface. Furthermore, in contrast with most rocks in nature, a monument is generally weathered in a microclimate like the climate of a more or less arid region and what is most important, percolation is practically nil. The water that comes into contact with the surface of a building can percolate in the rock only briefly before it evaporates or flows off. Hence the typical alterations, if monuments are leaching, resulting in decolouration at the surface or immediately underneath, formation of crust, concentration of chalk and other salts of moderate solubility in the crust, more or less short-lived efflorescence at the surface etc.

Investigation of the Causes of Decay

Analytical Methods

The cause course and extent of damage can be studied with minimum amount of sample through various analytical instruments. The proper selection of the methodology depends on

1. Characterising the surface or near surface.
2. Identifying amorphous and crystalline materials.
3. Determining spatial changes in composition (chemical analysis for materials heterogeneous on the micrometer level).
4. Determining the relative bond strengths as a function of physical and chemical alteration.

The following analytical methods become useful based on the above criteria:

- a. **X-Ray Fluorescence Spectroscopy:** The instrumentation used falls into two broad types described as Wavelength Dispersive or Energy Dispersive. The power of x-ray fluorescence lies in its use for elemental analysis.
- b. **X-Ray Diffraction:** The crystalline powder of the stone will produce characteristic patterns, which is an useful tool for getting information on the crystalline phase and nature of bonding.
- c. **Electron Microprobe and Scanning Electron Microscope (SEM):** The electron microprobe and the Scanning Electron Microscope were developed as separate instruments, the first using a crystal or wavelength spectrometer while the second utilizing energy dispersive system for x-ray identification. Their similarities and advantages have been combined in modern instruments for information about elemental composition, particle size orientation as well as textural details such as packing density, void space etc.
- d. **Electron Spectroscopy for Chemical Analysis (ESCA):** This method uses the distribution of electrons ejected from target material, which is irradiated with x-rays, uv or electrons. This method becomes a powerful tool.
- e. **Reflection Radiometry:** *In situ* analysis by visible and near - infra-red reflectance radiometry is of special interest since the method uses the radiations reflected by the sun or an artificial source to record the electronic (atomic) and vibration (molecular) interaction on the surface of material gives valuable clues about the weathering phenomena. The hand held radiometer of the size of a suitcase finds use to determine the depth of alteration leaching.
- f. **Neutron - Gamma Techniques:** The method involves the measurement of gamma rays that result from the interactions of the material under analysis. The method has been useful in yielding information about hydrogen content and thus leading to clues about bonding.

Weathering - Physical Properties

Measurement of physical properties of stone becomes very important in judging the durability and also for determining the extent of weathering. The following properties are worth consideration:

1. **Density:** Grain density is the ratio of grain mass to grain volume of the stone. Bulk density is mass of grains divided by pore volume plus grain volume. Bulk density becomes more reliable since grain density measurements are handicapped by incomplete saturation of inaccessible pores.
2. **Porosity:** Porosity is defined as the ratio of pore volume to bulk volume. It is found that igneous and metamorphic rocks have porosity less than 5 percent whereas sedimentary rocks have high porosity to the extent of 40%. Weathering of stone has direct bearing on porosity because they are receptacles for fluids and sources of weakness for ambient stresses.
3. **Permeability:** Permeability is defined by Darcy's law in which the flow depends on the stone and on the pressure and viscosity of the liquid.

$$Q = \mu P / \eta CL / A$$

where Q is the discharge in cubic cm per second μ is the permeability in darcis P is the pressure difference in bars η is the fluid viscosity in centipoises, L is the distance of flow in centimeters and A is cross sectional area in square centimeters.

Thermal Properties

Behaviour of stone over the changes in temperature of the surroundings can be significant of a microscopic scale. The study of the following parameters becomes significant:

1. **Thermal Expansion and Contraction:** Constituent minerals of the stone are isotropic and have different thermal expansion. The variation in temperature can cause stresses between the

mineral grains of the stone, which ultimately results in the micro-fractures. This irreversible change can cause greater permeability.

2. **Thermal Conductivity:** Thermal conductivity is the rate at which heat is conducted in millicalories per second through a 1cm^2 down a temperature gradient of 1°C over 1cm length. Thermal conductivity of stone is 20 - 50 times lower than metals and is dependent on mineral composition and porosity and becomes important in weathering mechanism.

Mechanical Properties

Measurement of the following mechanical properties become relevant in understanding the extent of weathering

1. **Hardness:** Hardness reflects on the strength of the stone and Moh's scale of hardness can be co-related with the properties of stone especially building stones of monuments.
2. **Elasticity:** The ratio of stress to strain is Young module of elasticity and can be used to detect porosity permeability and susceptibility changes in weathered rocks.
3. **Compressive Strength:** The compressive strength of a stone gives a clear picture of its strength and the extend to which decay has proceeded and also its capability to hold the load in monument.
4. **Friability:** The friability of stone is a measurement to determine the extent to which it can withstand breaking and crumbling and is determined by abrasion - hardness test. The test becomes useful in determining the character of the intergranular bonds.

Other Properties

The properties, which have indirect bearing on the decay of stone are colour, transmittance and reflectance, electric and magnetic behaviour etc

Colour of stone and its changes are reflected on the weathering and are important for aesthetic reasons. Transmittance and reflectance provide clues about cracks as light reflected from mineral cleavage can be detected.

Electrical Properties

Permeability, saline water content and pores of the stone can be understood by studying resistivity and dielectric strength of stone. Resistance decreases rapidly as porosity and water content increases.

Chemical Weathering of Igneous and Metamorphic Silicate Rocks

The chemical alteration of silicate rocks involves three simultaneous processes.

- a. Breakdown of the structure of the primary minerals and consequent release of various cations and silica, the later in more or less polymerised forms.
- b. Removal of a part of the above mentioned constituents in solution.
- c. Rebinding of the residues with components of the atmosphere such as water, oxygen and carbon dioxide to form new minerals that are more or less stable in respect to the new environmental conditions.

In general, the final balance involves a reduction in calcium, sodium and potassium and a corresponding increase in water, aluminum and iron. At the end of the process, the mass loss may be 60% or even greater if the water is free to percolate and to carry off in solution or suspension the elements and particles released by the chemical action of atmospheric agents.

Minerals are attacked by slightly acidic aqueous solutions (because of the presence of carbonic acid) and progressively transformed into a succession of secondary intermediate minerals that vary

according to the original mineral and/or the prevailing environmental conditions.

Conservation

Before proceeding to any type of intervention the following inquiries should necessarily be made:

- a. A detailed petrographical study of the stone in question with particular attention to textural and structural features.
- b. A study of the physico-technical properties of the stone such as type of permeability, absorption and linear dilation coefficients, cohesion, resistance to abrasion.
- c. A study of the stage of alteration of the rock, especially of its less altered parts, which are thus in the early stages of alteration as well as the 'fresh' rock to check for the possible presence of primary alterations.
- d. A check on the presence and activity of microorganisms.
- e. A microclimatic and even macroclimatic study, in much as the various surfaces of structures may not be in the same condition in this regard.

The above inquiries are always necessary, because the type of degradation and hence the appropriate countermeasures are never the same from one rock to another and even for the same rock in different macro environments. It should be kept in mind that as with all irreversible processes, it is much easier to prevent the alteration of a rock than to cure it. While it is important to take measures to preserve deteriorated surfaces it is indispensable to protect unaltered or barely altered ones before the attack by chemical weathering has had a chance to spread. The life of such surfaces can be prolonged almost indefinitely by a moderate expenditure in maintenance. That is why it is important to study the least altered portions of monuments in order to intervene before the progress of degradation renders intervention useless.

The main problems, which have to be tackled in conserving the stone monuments under tropical conditions (are listed below) are:

1. Minimising the action of rain water and moisture.
2. Stoppage or reduction of leakage (moss, lichen, algae plants).
3. Eradication of vegetation (moss, lichen, algae).
4. Reduction of the effect of isolation and erosion by dust-laden winds.
5. Minimising the damaging effects of atmospheric pollutants, particularly sulphur dioxide and particulates.
6. General consolidation and protection.
7. Structural stabilisation of monuments.

Consolidation and Surface Coatings

The history of application of consolidants goes back to 1st Century B.C., where application of wax on stone is described.

Treating with materials that will effectively restore the bonds between grains can restore the loss of integrity as a result of weathering. A range of stone consolidants have emerged, which can be grouped as:

- a. Inorganic materials
- b. Alkoxysilanes
- c. Synthetic organic polymers
- d. Waxes.

Inorganic stone consolidants work on the principle of producing a precipitate on the void space and pores from a liquid or by chemical reaction of the liquids with stone. Problems faced on poor performance of the consolidants due to less penetration, questionable ability to bind particles of stone together and the formation of soluble by-products etc. To overcome this precipitation of siliceous consolidants like alkali silicates, silico fluorides, alkaline earth silicates etc., have been used to precipitate silica or insoluble silicates from a homogenous solution.

Alkoxysilanes are a family of monomeric molecules, which react with water to form either silica or alkylpolysiloxanes. They are considered to be the most promising consolidants for siliceous

sandstones because of deeper penetration and also of the fact that polymerisation can be controlled to effect deeper penetration. Though the strength of the treated stone improves, the weathering pattern completely differs from the original stone after treatment.

The application of synthetic polymers works on two mechanisms. They are,

- a. The polymers as solution (using appropriate solvent) are deposited in the void space and pores as consolidants.
- b. Monomers either in pure form or as solvent are polymerised inside the stone.

Both thermoplastics and thermosets have been used to consolidate stone. Thermoplastics like poly vinyl chloride can be reversibly melted for application, whereas the thermosets like polyester and epoxy, once applied are irreversible. Waxes can be applied either by using solvent or as molten material directly or by melting it. Wax application is often handicapped by formation of tarry substances and the tendency to entrap dust and dirt.

Polymer as Protective Coating

The principle is to deposit monomers or pre-polymers on the surface of the stone and to polymerise them to form protective coatings to prevent erosion of stone surface. The effectiveness depends on mechanical properties of the composite and the stability of the interface between stone and the polymer and also the permeation characteristics of the polymer coatings.

Several tests like accelerated ageing are available to determine the effectiveness of consolidants or coating materials and the impact of treatment over the stone.

Conclusions

Though we have improved our understanding on the cause and course of stone deterioration and have advised the techniques employed for tackling the problem scientifically still we cannot

boast of having reached at least near the target. In India several institutions are engaged in the task, but we cannot claim that even our world heritage monuments like Shore temple of Mahabalipuram are above the danger mark. The situation would have improved considerably, if there had been a coordination between researchers in conservation with those of other institutions engaged in pure and applied scientific study of stone in CSIR laboratories, universities, IITs etc. As in other areas of conservation, we have acute shortage of trained conservators. This often is linked with the status of conservators and conservation, which we could not break the ice in India though we have made several resolutions and recommendations in common forum like this.

I am sure, our deliberations, in the pioneering laboratories of India viz., the Chemical Conservation and Research Laboratory of the Government Museum, Chennai, which has produced several eminent conservators and have emerged with solutions for various complicated problems in conservation, several specific issues on stone deterioration will be discussed and solutions reached.

International Seminar on Conservation of Stone Objects



The Honorable Minister for Education,
Dr. M. Thambudram delivers the inaugural
address. Dr. I. K. Sharma, Dr. B. Karmali,
Dr. H.A. Ibrahim, Mr. S. P. Singh,
Mr. K. Lakshminarasimhan
are on the dais



After the Inauguration the Honorable Minister
goes round the Exhibition



A View of the Exhibition on
Conservation of Stone Objects



A View of the Stone Carving Workshop
during the International Seminar

International Seminar on Conservation of Stone Objects



Dr. Stephan Furler presents his paper at the International Seminar



Dr. Baldev Raj, Director, Materials and Chemicals Representing Group, Indian Institute of Space Research and Technology, Kalamangal, delivers the Valedictory Address. Dr. Baldev Raj, Dr. R. Kannan, Dr. K. V. Raman, Dr. L.K. Bhargava, Dr. D.A. Goudar, Mr. A.K. Bhat, Mr. K.P. Singh, Dr. V. Jayaram, Mr. R. L. Piplai are on the dais.



Participants of the International Seminar on Conservation of Stone Objects with Special Reference to Lustrous Objects with the Organisers



Participants of the International Seminar near Stone Temple, Mahabaleshwar

Summary of the Proceedings of the Seminar on Conservation of Stone Objects with Special Reference to Limestone Objects

After the Presidential Address was delivered by Dr. R. Kannan, Commissioner of Archaeology and Museums who also read out the report on the important events in the 150 years of the Government Museum. Dr. R. Kannan gave out the size of the Web site as 1400 A4 size pages corresponding to 122 MB developed by M/s. Electronic Corporation of Tamil Nadu (ELCOIT) for which the Commissioner and Curators had to work till late night for one year. He also claimed that it is one of the biggest web sites among the museums in the world. He outlined the medium term vision plan of the Museum. Dr. D.A. Swallow and Dr. I. K. Bhatnagar felicitated the Government Museum on its 150 years. Dr. Bhatnagar gave a brief report on the activities of the Indian Association for the Study of Conservation of Cultural Property (IASC). Dr. Swallow spoke about how the Nehru Trust sponsors Curators to London. Dr. V. Jeyaraj gave a report about the conservation activities in the Department of Museums. The Hon'ble Minister of Education, Government of Tamil Nadu, Dr. M. Thambichandran inaugurated the Seminar and the Web site and the special exhibition on Stone Objects. In his address, the Minister congratulated the Museum for the various activities undertaken by it and also the programmes of the 150th Year Celebrations. He also lauded the development of the Web site and declared that the Amaravati limestone objects embedded on the walls would be removed, conserved and redisplayed according to modern museological standards. Mr. S.P. Singh, Secretary, IASC proposed the vote of thanks.

The keynote address was delivered by Dr. M.V. Nair, Director of Archaeology, Kerala on Conservation of Stones as Cultural

Property i.e., limestone, sandstone and how it weathers and deterioration of stone due to air pollution, how to analyse the properties of the stone by reflection radiometric, neutron gamma techniques and how to analyse the physical problems due to weathering by density, porosity etc., and how to conserve them after considering the thermal properties. He has advocated consolidating and surface coating and co-ordination between researchers in conservation and actual professionals.

The first technical session was presided by Dr. I.K. Bhattacharjee and Reporteur by Mr. P. Perumal. Prof. T. P. Jagan, on Geological Aspects of Rocks Used for Art Objects (Sculptures), stated the geological aspects of the sculptures. Dr. J.Raja Mohammad, Curator for Government Museum, Pudukkottai on Medieval Monuments of Pudukkottai Status of Granite stated that the deterioration and decomposition on the surface of the granite holdings of some of the early Chola monuments and their present status, Prof. M. S. Mathews, Head of the Department of Civil Engineering, IIT, Chennai on 'Restoration of Earthquake Damaged Stone Monuments with Special Reference to Gujarat Monuments' stated that - [Mathematical Modelling] FEM Analysis and also structures cannot be made earthquake-proof, only resistant to earthquakes. There is a need to adopt and adapt these internationally accepted anti-seismic retrofit and rehabilitation techniques to conditions in India and simultaneously train manpower in their use, to ensure conservation of our monuments for posterity.

The second technical session was presided over by Mr. A.S. Bhat and Reporteur by Mr. Y. A. Divya Durga Prasad. Mr. S.P.Singh on 'Natural and Manmade Disasters with Special Reference to Barabar Statues and Art Objects at Bhub'.

The third technical session was presided over by Mr. S. P Singh and Reporteur by Mr. P. Sam Sathian. Mr. K.T. Narasimhan, Superintending Archaeologist, Archaeological Survey of India, Chennai Circle on 'Conservation of Stone Monuments'. In India,

the ancient monuments were made of three types known as *Nagara*, *Dravida* and *Vijaya* with special reference to temples. They were made with various media like stone, wood, brick, stone-cum-brick etc. The Archaeological Survey of India, Chennai Circle, Chennai during the recent years has completed conservation of more than 100 temples successfully without deviating from the ancient method. For doing conservation, the conservator should have the knowledge of art and architecture, ancient knowledge about the raw materials, well versed with modern technique of methodology, besides capable of using modern materials also. Mr. C.B.Gupta presented a paper entitled 'Time for Conservation of Limestone Objects - a report'.

The fourth technical session was presided over by Mr. K.T. Narasimhan and Reporteur by Prof. T.P. Jagan. Dr. M. Sekar presented a paper on 'Deterioration of Stone Work and Methods of Restoration'. He stated that in undertaking restoration work of the affected structure, the sequential action suggested are diagnosis, cleaning, pre-consolidation, consolidation, surface protection, reconstruction and maintenance. The repair methods range from stitching of the cracks to redressing of the stone when the original surface has eroded. Mr. R.K. Sharma spoke on 'Conservation of Stone Objects with Special Reference to Limestone Objects'. Mr. N. Harinarayana spoke on 'A Short Note on the Preservation of the Brick-built Heritage of Chennai'. He stated that brick is similar to stone as a building material in some respects but has its own problems concerning conservation.

The fifth technical session was presided over by Dr. M. P. Bhatnagar and Reporteur by Mr. C.B.Gupta. Prof. P.K. Palanisamy on 'Preservation and Conservation of Stone Antiquities Using Laser' - The intriguing properties of lasers, the mechanism involved in the stone cleaning by lasers and also some of the recent developments of the laser technology of cleaning are presented in this paper. Dr. Stephen Fowler on 'Lasers for the Conservation of Cultural Heritage'. The development of new

methods that are less invasive than was previously the case, an example being laser-based techniques for the clearing, recording, non-contact replication and analysis of sculpture. Ms. M.N. Pushpa spoke on 'Stone Objects and Bio-deterioration with Special Reference to Limestone Objects'. Dr. R.R. Deshpande and Prof. A.D. Agate spoke on 'Association of Specialised Microbial Population with Rocks of Ajanta and Aurangabad Caves'. He stated that it is difficult to establish a clear cut cause - effect relationship. Mr. S.P. Singh and Ms. Chhavi Bhandari spoke on 'Problems of Bats on Indian Monuments'. They stated that the problem of bat eradication from monuments is still unsolved. The bat's entry into monuments can be controlled by putting bat boxes along the sides of the point of entry of bats into monuments and closing that point of entry by wire meshes for the period till bats actually divert their way to bat boxes.

The sixth technical session was provided over by Dr. D.A. Swallow and Reporteur by Dr. C. Maheswaran. Dr. Robert J. Knox spoke on 'Display of Amaravati Sculptures in British Museum'. He spoke about the problems of Amaravati limestone sculptures both in the storage and display area. The present display system and air-conditioning the gallery have made the Amaravati limestone sculptures in good condition. Mr. P. Sam Sathiaraj, on 'Problems Relating to Transport and Display of Stone Sculptures in the District Museums in Tamilnadu' - Limitations of funds allotted to the district museums for adopting sophisticated methods of lifting, loading, packing and transporting the sculptures is also another reason for the occurrence of these problems. Ms. Y. A. Divya Durga Prasad spoke on 'Traditional and Modern Methods of Poulticing in the Removal of Accretions from Stone Sculptures'. Traditionally the sculptures are cleaned to remove oil and other accretions by the application of flour, cooked rice and sandal powder paste on the sculptures by the simple principle of capillary action. When the sculptures are brought to museum and

similar places from the place of their occurrences, problems start increasing.

The seventh technical session was presided over by Dr. R.J. Knox and Reporteur Mr. G.B. Gupta. Dr. R. Kannan spoke on 'Overview of the Legislative Framework for the Protection of Our Cultural Property and Suggestions for Improving Implementation'. He stated that laws have been framed to regulate traffick in antiquities. It is illegal to trade in them or export them without permission. Therefore, there is need to protect them so that they do not end up in the illegal art market. Mr. C. Paranthaman spoke on 'International Law for Protecting Objects of Art from Illegal Trafficking and Theft'. Mr. C. Santhalingam spoke on 'Authentication of Stone Sculptures'. He stated that in dating the sculptures, scholars usually rely upon the physical features, dressing pattern and ornamentation. But fortunately some of the sculptures are having inscriptions with exact date and help us to fix the actual date of the sculptures.

The eighth technical session was presided over by Mr. B.R.N. Sharma and Reporteur Mr. M. Gandhu. Mr. A.S. Baht spoke on 'Three Main Problems of the Sculptures' - 1. Technical study of the stones used for making these sculptures to authenticate them and study their provenance and history of technology, 2. Scientific study of the deterioration process resulting into crusts or erosion or weathering. This helps in devising suitable treatment methodology and 3. Suitable display and storage technology as to retard their decay as long as possible. No decay should happen of objects due to wrong display and storage techniques. Mr. Shah Abdel Monaf on 'How the Young Sculptors Foresee Their Future? - An Anthropological Study'. Mr. Rita Jain on 'Bringing Conservation to Classroom - An attempt'. Mr. M. Gandhu on 'Preservation of Stone Objects in the Government Museum, Vellore. This paper deals with limestone, sandstone, sculptures, the mutilations done to the objects, the type of preservation and dowelling, which is a technique of restoration of stone sculptures.

Mr. N. Sundara Raman on 'Stone Objects and Their Environment' and Mr. N. Soundara Pandian on 'The Role of Curators in Preserving Stone Objects'.

Prof. Dawn Stanley spoke on Stone Structures with an Natural Caverns: Need for Conservation and Protection. Dr. V. Jeyaraj spoke on the Status of Preservation of the Amaravati Limestone Sculptures in Government Museum, Chennai and the participants were taken to the Amaravati Gallery to explain the various problems. Ms. J. Christy Veda spoke on Stone Sculptures and Their Preservation Measures in Tamil Nadu.

— Dr. R. Kannan

Valedictory Address by Dr. Baldev Raj

Conservation of Stone Objects with Special Reference to Limestone Objects

Baldev Raj and B. Venkataraman,

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India is a country endowed with a rich and varied cultural heritage. Apart from the exquisite South Indian bronzes, the stone and marble objects and limestone reliefs occupy a pride of place in the country and are known internationally for their aesthetics and uniqueness. The wonder of the world Taj Mahal, the monolithic rock cut *pancharathas*, Shore temple at Mamallapuram, the *Amaravati* limestone sculptures and the limestone reliefs such as "second century *Mamabata* the *Cakrasanti*" at the Government Museum, Chennai are all standing examples to these. Apart from being the cultural assets, objects of cultural heritage form a vital link between the past and future generations. They also serve as ambassador of a country. Hence, it is highly important that these treasures be characterised and conserved for posterity.

Conservation refers to the art of preserving the originality of an object without doing any alteration to the physical features by applying natural, physical and chemical methods. It is distinct from repair or restoration but includes both restoration and preservation. Stone objects in museums are often perceived as a material with few problems and thus requiring the least attention. This is not true. Stone is brittle and can break or shatter. While stone is generally harder and tougher than many other materials, the factors, which cause deterioration of other museum objects including environmental conditions also affect stone and

limestone objects. The process of deterioration and decay is unavoidable and continuous and so is the process of restoration and conservation. An effective conservation measure requires a complete understanding of the historical, stylistic, iconographic, as well as technological and material aspects of the cultural property. Precise and reliable characterisation of stone especially limestone objects is a demanding task since one is required to do a detailed and comprehensive study without violating the antiquity of the object. This requirement calls for completely non-destructive techniques to be employed. Conservation of these objects is a daunting task since the mineralogical materials present in the objects to be preserved as well as the conservation materials applied are very similar and allow no separation by content or cause further deterioration.

In this paper, we briefly highlight the agents that cause deterioration of stone especially limestone objects and the present day conservation measures. An international case study is highlighted as to how an integrated approach involving the application of scientific techniques can help in effective restoration and conservation.

Agents of Deterioration in Stone and Limestone Objects

The agents of deterioration that can have the most profound effect on stone and limestone objects are the direct physical forces. Most stone objects get chipped, cracked or broken on being dropped while limestone objects can break or crumble. Thus, careful handling of these objects is required to prevent any possible cumulative damage. Stone or limestone objects may be housed inside museums or protective environments or may be in open environments. In case of objects in open environments,

(i) Dirt and dust accumulate on horizontal surfaces and in nooks and crevices. This disfigures the object. Over a period of time the dirt can penetrate porous stone and cause staining. High traffic areas will have greater accumulation of dirt.

(i) Cyclic changes in humidity and temperature can bring salts to the surface and cause spalling. High humidity can react with pollutants and damage stone and limestone structures.

(ii) Erosion would occur due to wind and rain.

(iv) Atmospheric pollutants can react with water and cause damage. Carbon dioxide and water form carbonic acid that can dissolve calcium carbonate, a major component in limestone and marble. Other sources of acid that attack stone come from the reaction of water with chlorides, nitrates and oxides of sulphur. Other chemicals from car exhaust and industrial pollution react with carbonates to create disfiguring brown and black layers on the surface or simply adhere to stone and discolor the surface.

(v) Biodegradation occurs through active macro floral growth. Bacteria, algae, fungi and moss grow on limestone and stone surfaces and inside cracks pushing them further apart. These agents also retain water and contribute to the damage caused by water and atmospheric pollutants. Their organic waste products can dissolve calcium carbonate. Biological agents can also cause staining. Birds can disfigure and damage stone with their waste.

Vandalism Can Damage the Objects

Except for erosion due to wind and rain and vandalism, objects that are housed in museums or protective environments are also subjected to other factors mentioned above. The net result of all these is a weakening of the structure, erosion and loss of features, development of cracks and defects and in worst cases the loss of the object itself. Thus effective conservation and protection measures are needed.

Present Day Conservation Measures

The program of conservation includes cleaning the objects, consolidation, repair and restoration. An additional step presently employed is to assess the effectiveness of restoration.

Cleaning

Cleaning is the most important step. Removal of dirt, dust and foreign particles from the surface of a limestone object deserves care and attention. The cleaning method should not damage or destroy the object itself. Cleaning can be effected either by (a) physical (mechanical), (b) chemical, (c) electrochemical/electrolytic methods or (d) by the combination of one or more of the above methods. Physical methods include use of simple mechanical tools such as pin, scalpel, chisel, hammer, mechanically operated vibro-tool, etc. Ultrasonic methods can be used to remove the extraneous matter and adherents by immersing the objects in a detergent solution contained in an ultrasonic cleaner. Vibro-tool may also be used to get rid of loose adherent soil and dirt. However, this technique calls for extreme care, for lack of it this may damage the finer workmanship of the artefacts. In chemical methods, usually chemicals which can dissolve or form soluble complexes with the corrosion products are used to remove the deleterious materials from the objects. Only mild chemicals and very dilute solutions are used to remove the corrosion products without affecting the limestone stone metal beneath. Mechanical means of removing deposits have the advantage over chemical means in that the former methods do not introduce or leave behind any additional chemicals or products of chemical changes on the artefacts.

One of the latest and innovative methods is laser cleaning. The precise and well collimated laser beam engages only those areas that need attention and has excellent removability. There is minimal damage to the surroundings and no after effects. A number of laser types are available, the most popular being the Nd-Yag Laser.

Consolidation and Conservation

Limestones may lose their integrity (i.e. decay) due to a number of factors listed above acting singly or in unison. Compared to other

stone structures, limestone being porous sedimentary rocks, the problem of decay much more severe. The decay is generally believed to result from the dissolution of the material cementing the grains of limestone together or from disruption of the intergranular bonds from increased tensile stresses caused by such processes as salt crystallisation and thermal expansion. Thus to restore the integrity of the decayed limestone object, it must be treated with a material also called consolidant that will effectively restore the bonds between the adjacent grains. Adequate care is to be exercised in the selection of consolidant since, the consolidant itself should not be the source of decay or damage or discolouration of the object. Consolidant should be selected based on adequate laboratory and field tests only. Different types of consolidant are used for different problems.

Dilute epoxy and acrylic resin systems in hydrophilic solvents have been used as consolidant for weak limestone while biocides in dilute aqueous solution have been applied for preventing microfloral growth on new limestone and for controlling in situ growth on historic limestone. Once an object has been consolidated, it is to be conserved. Protective coatings have been applied as part of conservation measures to prevent weathering. In case of objects inside museum, special enclosures are made for housing such objects. This would not only prevent the object from being exposed to adverse environmental conditions but also from public handling, dirt and dust. The latest research focuses on artificially induced surface conversion of calcium carbonate to calcium oxalate to protect limestone from the destructive effects of acid deposition without inhibiting the natural behaviour mechanism of the limestone.

Case Study – Restoration of Fountain of Four Seasons at Iowa State University¹

This case study highlights the systematic approach adopted in the restoration of the Fountain of Four Seasons located at the Iowa State University, USA. This fountain had been sculpted in 1936

by Danish born sculptor, Christian Petersen and is based on the Osage Indian legend, which gave thanksgiving for the provision of maize. The arrangement in the fountain consisted of four Native American women made from Limestone, each representing one line from the legendary chant. Accompanying the figures were eight unglazed terracotta panels and associated capstones and spouts, which were attached to the fountain basin. The fountain had an exterior limestone perimeter wall.

Over the years due to neglect the fountain had deteriorated. Improper water treatment had resulted in formation of thick scale deposits and biological growth over most of the limestone figures and the terracotta panels while advanced level of corrosion found on the fountain's water recirculation system resulted in disfiguring ferrous stains on the terracotta panels. Cracks were observed on the east-facing terracotta panels and around the neck of the north-facing limestone maiden. Overall, several areas in the concrete bases of limestone sculptures and terracotta panels had deteriorated.

The entire fountain was dismantled for the purposes of conservation. The eight terracotta panels, capstones, downspouts, associated pieces, and four limestone sculptures of the maidens were shipped to Conservation Technical Associates' conservation facility in Connecticut for conservation. Prior to the actual conservation treatment, cleaning tests and material analysis were performed on the four limestone sculptures and the central terracotta wall to ascertain the best method for cleaning and also identify appropriate consolidants and chemicals that would be suitable for conservation. Ultrasonic cleaning carried out to remove surface dirt and biological growth while the hairline cracks in both terracotta and limestone were repaired using *Jokal* 52 Epoxy tinted to match the colour of the surfaces. To prevent recurrence of rust staining on terracotta panels and limestone sculptures all ferrous parts within the recirculation portion of the

fountain were replaced with 304 stainless steel rods. After conservation, all the parts were shipped back and assembled.

Role of NDE in Conservation

Non-destructive Evaluation (NDE) methods such as ultrasonics, acoustic emission, radiography, tomography and infrared imaging are becoming increasingly important in developing long term strategies for scientific characterisation and preventive conservation². Acoustic emission/microseismic activity is a valuable tool for diagnosis and monitoring in stone conservation programs. One of the fundamental application areas is evaluating the stability of the rock foundation of the monument and also the monument itself as an architectural object. Ultrasonic and radiographic methods have been used for characterisation of the objects and also evaluation of defects such as cracks in objects prior to conservation treatment. Digital documentation based on high resolution CCD camera coupled with periodic monitoring and image processing with template matching have been envisaged for revealing deterioration at a very early stage. In fact, innovations in the field of NDE Science and technology is being exploited for conservation applications.

Issues in Conservation

Objects of cultural heritage are the ambassadors of the country. Many of the local and national authorities value cultural resources primarily for their potential to attract foreign visitors. However, uncontrolled and unplanned tourism can cause irreparable damage to the object itself. This coupled with the fact of poor maintenance can result in the loss of the object itself in the long run. The main issue that exists in many developing countries is that while there is a desire for the income generated by the tourism industry, there is hesitancy to provide the funds necessary for conservation and maintenance. Apart from this, the other issues include lack of awareness among the general public, paucity of training programs in conservation and lack of availability of

trained manpower. Another major handicap in developing countries is the lack of synergism between various institutions such as archeological bodies, ministries, research centres and universities.

Conservation – Quo Vadis ?

The process of decay is continuous and unavoidable and so is the process of conservation. The two familiar maxims – “A stitch in Time Saves Nine” and “Prevention is Better than Cure” highlight the need and principles of conservation. Internationally conservation policies have aimed at appropriate methodologies for early detection of decay and also strategies to find the root cause of decay. The case study on fountain of four states is an excellent example which highlights how conservation of objects of cultural heritage is an interprofessional discipline coordinating a range of aesthetic, historic, scientific and technical methods. The issues in conservation clearly indicate that a paradigm shift is needed in the approaches of developing countries and the conservation personnel. It is to be realised that ultimately success in this field depends on how experts from the fields of art, architecture, material science, technology and administration respect each others contribution and combine to form an effective team.

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General Papers

Characteristics of Different Stone Objects

S. P. Mohan,

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Stone is a construction term for natural rock materials, quarried from the earth for building purposes. Both the aesthetic and engineering qualities of stone are derived from the mineral content of the stone and the formation processes.

To be usable as a building material, the rock must be able to be cut and removed from the source in large enough dimensions to be useful in the building process. Those pieces removed must be free from fractures and devoid of minerals, which might break down chemically or by weathering.

Strength

Very generally, stone can be considered to be a material, which is very high in compressive strength. Stone materials in the US range from 7000 psi as a low for sandstone to 25000 psi for certain granite.

- ◆ Primarily used in compression - not to support other forces
- ◆ Stones are also very heavy and much of their strength in wall construction is used to support their own dead load.

Durability

Durability is resistance to weathering, mostly. Much failure in stone in construction is due to weathering or natural forces: water, freeze/thaw cycles, fire. Air pollution and acid rain-rapidly deteriorate stone structures throughout the world-major issue in historic preservation. Stone materials for construction are very regional in nature, tied very directly to local geology. Stone used

in building in the past was generally closely tied to the regional sources.

In architecture-often used for building foundations-transition from building to ground-a solid base for the building.

In landscape-most suited to uses tied to the ground-retaining walls, low free-standing walls-paving.

Igneous Rocks

Igneous rocks-essentially cooled molten matter. Igneous rock is crystallised from molten matter. Examples of igneous rock include: granite, gabbro, basalt and porphyry. The differences between these stones are chemical composition and grain size. Chemical composition will affect both colour and texture. The texture of these rocks also depends on the environment in which they are cooled-may be slowly deep in the earth's crust or rapidly near to the surface.

Granite

True granites are cooled deep below the earth's crust and have an even, evenly grained crystalline texture-some are relatively fine-grained, some quite coarse grained.

Granites have high silica (acidic) content in the magma - this crystallises into quartz. Typically, the higher the quartz content, the stronger for building construction.

Granite is a very hard, durable material, which can be prepared in a range of finishes from very rough split face to a highly polished surface. Tends to cleave or split regularly.

Not typically sculpted because of hardness. Very expensive to cut or carve granite, although it is done.

Granite is used where high strength and/or durability are needed. It has excellent resistance to weathering and abrasion, therefore is an ideal stone for landscape applications. At the turn of the century cobblestones for streets were typically made of granite - can be seen in many historic districts now.

Basalt

A "basic" rock, very fine-grained, very dense and virtually without crystals. Basalts are generally low in silica content and higher in the dark minerals-hornblende, black mica. Basalts are the result of intrusive bodies-cooled rapidly near the earth's surface, resulting in a very fine-grained texture.

Eugene basalt is very dark grey to black in colour. In the past it was used in the landscape extensively for walls and flagstone paving. Currently, it is used less frequently.

Workability

Basalt does not split regularly - must be chiseled into shapes. Rarely seen highly finished, especially now.

Sedimentary Rocks

The raw materials of sedimentary rocks are sediments, weathered and carried by water. These silts, sands and occasional skeletal remains are deposited by the action of water (either mechanical or chemical as in precipitation) and compressed under pressure.

Essentially - weathered rock of all derivation mixed with plant and animal remains and compressed - often under the weight of water bodies or glaciers. Examples include - sandstone, shale, limestone, dolomite, travertine and onyx. The flat layered structure of sedimentary rock is an essential characteristic. They also often have an uneven texture (called graded stone), in some cases with recognisable plant and animal remains or rock within the stone.

There are two important components to sedimentary rocks, which define their characteristics: the primary materials and the cement.

Texture, colour and grain are dependent upon the material composition of the primary components and the bedding or layering characteristics. The sedimentary rocks generally have the least resistance to weathering and wear, however, they are also

generally very easy to work - easily cut or sawn and easily sculpted.

Limestone

Rock, which consists primarily of calcium carbonate (pure limestone is 100% CaCO_3 , pure clay is 0%), formed either directly or indirectly from minerals dissolved in sea water. **Chemical limestones** are formed directly by the precipitation of calcium carbonate from water. **Organic limestones**, with which we are probably most familiar, consist largely of fossilised shell bones and plant remains. **Clastic limestones** result from the erosion of pre-existing limestones, later re-consolidated. Limestone is relatively soft when it is taken from the ground and at that time is quite workable. As it is exposed to the air, it hardens, becoming quite durable and weather resistant.

Travertine

Travertine is a very finely grained form of limestone, often with very visible layering - can be visually confused with marble - appearance is halfway between the two.

Sandstone

A sedimentary rock composed primarily of silica - either rounded or angular grains of sand cemented together by a range of mineral compositions such as silicas or clay-based minerals, giving sandstones their colours, ranging from white to deep reds.

Durability and Workability

When quarried, sandstones have relatively high water content, making them easy to cut and sculpt. They are relatively durable and strong once dried, often lighter than most other stones, however they are also much less resistant to wear and weathering. Sandstones are infrequently used for paving for this reason, frequently used in sculpting applications.

Metamorphic Rocks

These are formed by the crystallisation or re-crystallisation of pre-existing rocks, under high pressure and heat. Because of this re-crystallisation process, the resultant rock is more stable and generally much stronger. Also can be more visually appealing.

Examples of metamorphic rocks include: gneiss, quartzite, marble, and slate. Gneiss and quartzite are formed from granites or sandstones, marble is formed from limestone, dolomite or travertine. Slate is formed from clay shale or marl.

Marble

Formed by the re-crystallisation of limestone. The calcium carbonate of the limestone is crystallised under extreme heat and pressure to form crystals of calcite. The coloured banding typical of many marbles (white, grey, pink, green) is caused by impurities in the original limestone. Marbles vary widely in their durability. Some are very durable, while others must be protected from weathering and wear.

Slate

Clayey rocks, subjected to pressure are reconstituted in the mineral form of mica, which lies in very thin plates at right angles to the pressure. Slates are usually exposed to low-grade metamorphism, many are incompletely metamorphosed. Slates generally do not have high strength due to the tendency to split horizontally, however some have good weathering characteristics. Slates can be split into very thin sheets - as thin as $\frac{1}{4}$ ". Slate has therefore been used for roofing as well as very frequently as a paving material. Slate is also the former material of blackboards - it can be sawn or cut to specific shapes, and can be polished to a very smooth finish. Colours are generally in the grey to blue-grey or green-grey.

Manufactured Stone

What is it? Stone fragments are bonded together either with Portland cement or epoxies to create materials resembling stone in appearance.

Stonework Terminology

Forms of Stone

Stone is marketed in a number of different forms referring to individual elements

Rubble - in its purest sense refers to fieldstone, however, it also is used to refer to non-cut stone, which might be blasted from the quarry.

Ashlar - refers to squared stone, usually cut by sawing or chiseling, depending upon the composition of the stone. Ashlar stone is available in a number of finishes, depending upon the source stone.

Dimension Stone - refers to cut stone, wholly fabricated at the mill, ready for installation in the building. An example might be the sills or lintels of a building or decorative details.

Paving Terms

Flagstone - as we might expect, refers to flat slabs, either worn, or broken, which are used for flooring or paving.

Riverstone - rounded rocks as typically found in rivers.

Cobblestone - paving units chiseled to roughly rectilinear shapes.

Stonework

Basic classes of stonework:

Rubble: Using rubble, constructing a wall with no apparent coursing. This may be the structure of the wall and it can be constructed either with or without mortar. It may also be a facing material only, in which case the stone is tied back to the wall with metal ties.

Coursed Rubble: Again, using rubble, the stone is laid up so that the "bed" joints are visible as horizontal lines. Has a significantly more ordered appearance than straight rubble stonework.

Coursed Ashlar: Ashlar stonework refers to the use of cut stone. Coursed ashlar refers to coursing of the dimension stone - laying it in horizontal beds or courses, much like standard masonry. In stonework, it is very common not to use matching sizes of pieces of stone.

Random Ashlar: Cut stone in random coursing.

Paving: No standard terminology specific to stone paving-borrow from wall patterning or brick paving.

Durability: Resistance to weathering and to abrasion.

◆ Durability in stone for construction can be listed from 5 years (sandstones) to 200 years (granites). But, how old are the ancient structures now? Greece and Rome - over 2000 years.

Strength: Compressive strength and with sandstones and slates, shales - tendencies to split or break

Weight: For design and transportation reasons

Labour: Are there experienced masons to build the project?

In summary, stone is considered an expensive material to use in landscape construction - looks nice and it can give a very elegant appearance to the landscape.

◆ It is very durable and long lived.

◆ If regional stones are used in appropriate settings - can create strong ties between the built and natural landscape.

◆ Can be inappropriately used i.e. in above ground conditions, out of the right landscape context, can be too rough or too finished or too heavy for the context.

Dimension Stone Granite

The Dimension Stone Granite (DSG) ranks second in exports, next only to iron ore. India exports DSG to Italy, Taiwan, Hong-Kong, Japan, China, USA, Germany, Belgium, France, Spain, Middle East, Singapore etc. There are about 300 varieties of DSG in the world market out of which nearly half of them are from India. India with DSG resources of 1,650 million cubic metres accounts for nearly 20% of the total world DSG resources. Granite industry in Tamil Nadu is in constant requirement of good quality dimension stone blocks for consumption, both in domestic sector and in overseas market. Fourteen varieties of DSG have been found in the four districts namely Tiruvallur, Vellore, Tiruvannamalai and Villupuram, of which black granite, black porphyry, pink/yellow, multi, desert brown and Gingee grey are of premium quality that are being exploited and exported. Grey pearl and zebra white are new finds.

Selecting Stone for Conservation and Restoration Work

The first requirement when a stone building is considered for conservation or restoration is to determine the nature of the stone. Many historic buildings will have archival records, which should be scanned for references to the source. Where that does not produce any answers a geologist should be consulted to determine the nature of the stone. The next stage, the determination of the 'provenance', the source of the stone, may be much more difficult. Again it is best referred to a geologist with specialist knowledge of the geology of stone for building and decoration. It must also be recognised that stone from a present day quarry, whilst geologically the same, may in fact present a slightly different appearance from stone quarried in the past. Nevertheless, to preserve the integrity of the building, the same geological stone is always to be preferred. However, it is not always possible to find the stone required. In that event a geologically appropriate stone should be sought and the re-use of original or reclaimed stone should be considered. Although many

masons object to 'second-hand' stone, there appears to be no scientific reasons why the material should not be re-used, provided that bedding and other criteria are observed. The matching of stone from a provenance other than the original is a specialist task. Again, advice should be sought from geologists with experience in this field. It may be necessary at this stage, for thin-sections to be cut for microscopic study or for x-ray diffraction techniques to be used. The specialist will give guidance.

Geological Aspects of Rocks Used in Sculpture

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The knowledge of materials for a Sculptor or an Artist is the foundation upon which real achievement is based. The knowledge of the technical aspects, physical and mineral properties of stones are important for an Artist and a Conservator. The great masterpieces give us not only the outstanding craftsmanship of the past, but also reveal the technical knowledge of the masters in choosing proper stones for sculptural works. It is very important that a Sculptor must have the knowledge of materials besides craftsmanship.

Definition of Sculpture

The term 'sculpture' is derived from the Latin word '*sculptor*' and '*sculptus*' meaning 'to carve' or 'cut-out stone'. The term is today employed in a wider and more inclusive sense. Sculpture is essentially a dimensional art concerned with the organisation of masses or volumes. The Sculptor composes his work in terms of volumes or masses, contours, light and dark areas and textures. Among various materials stone, wood, metal, plastic, earth clay, wax, ivory and bone are some to mention. Each substance has its individual colour, texture and hardness. Sculptural media are roughly divisible into two large groups, one consisting of the hard and relatively permanent substances such as stone, wood and metal, which are either carved directly or beaten into final shape and the other consisting of the soft substances such as plastic, earth carved directly or beaten into final shape and the other consisting of the soft substances such as plastic, earth clay and

The materials used in carving are generally hard substances and sculptors, both carved and modelled masterpieces, have been produced in both forms. Sculpture consists of two major divisions, namely carving and modelling. For purposes of classification, we can divide sculpture into three major forms.

1. Intaglio, 2. Reliefs and 3. Sculpture in Round.

Intaglio

Intaglio is a form of incised relief in which the design is sunken below the surface. A type of incised relief employed largely by the Egyptians in the pyramids for architectural purposes is referred to as Egyptian relief. In the intaglio form, the figures do not project from the wall, but are cut into it. This sunken relief is characteristic of Egypt and rarely found elsewhere.

Reliefs

The term '*bas relief*' is frequently used in a broad sense to include all types of raised reliefs. The difference between the type or degrees of relief is a difference of degree of projection from the background surface or plane. Low relief is referred to as *bas-relief* '*bas*/'*relievo*' the French word and '*basso*' the Italian one, means 'low'. This type of relief sculptures have relieve projection from the background and have no undercut medium. Relief is also known as '*mezzo*' '*relievo*' or 'half relief'. Another type of relief is full relief known as '*high-relief*' and '*alto-relievo*'. This is the highest type of relief. The forms in this relief, depicting some projections such as heads or arms, may be entirely free from the background.

Sculpture in Round

In sculpture in round, the figures of forms are free standing and can be seen from all sides. The round sculpture gives three dimensional forms in detail. Sculpture in the round is the nearest and most intimate approach of the arts to life since its essence is three-dimensionality. While a painter works on a

two-dimensional basis and suggests the third dimension, the Sculptor works directly with three dimensions.

The Tradition of Making Stone Sculpture

The tradition of making stone sculpture in stone can be traced to prehistoric time. The best example of pre-historic sculpture is the Venus of Willendorf, 28000-25000 B.C., also known as the Great Mother Goddess. The Egyptian pyramids and sculptures date back to 5000 B.C., like the Temple of Ramses II, 1257 B.C., Mentemhet the Governor sculpture, 650 B.C. (Egyptian Museum Cairo) and the bust sculpture is Queen Nefertiti, 1360 B.C. Pyramids, spinx and other important monumental sculptural works are to be found in the Middle East, India, Iran and Iraq.

Various Kinds of Rocks Used for Making Sculptures

Rocks fall into three major divisions, according to their origin. Those that have been formed by the action of fire—the igneous rocks, those that have been formed by the action of water—the sedimentary stones and those igneous and sedimentary varieties, which have been radically changed physically or metamorphosed by natural forces—the metamorphic rocks.

Igneous Rocks

Igneous rocks are formed by the cooling and solidification of subterranean or molten masses as they approach the surface of the earth. The igneous varieties include diorite, porite, rhyolite and obsidian.

The Temple of Ramses II, 1257 B.C., in Egypt, which is 60' in height, is a typical example of this kind of stone sculpture. Other important round sculptures in granite are the statue of Kafee and Mentemhet the Governor, 650 B.C. Egypt.

Granite

The origin of the term 'granite' is not accurately known. It might have been derived from the Latin word '*grasser*', meaning 'a seed' or 'grain', because of the granular texture of the stone. Another

possibility is the Italian word '*granito*' (*gran*) referring to the varicolored grains. The term signifies any entirely crystalline unstratified granular rock mass of igneous origin made up principally of quartz and a potash feldspar, which is a very hard material. It has been extensively used for making sculpture till date by sculptors all over the world. The best possible quality should always be used in any other stone selected for sculptural use by sculptors.

The Essential Minerals of Granite

Feldspar Group – Quartz, Orthoclase, Microcline, Albite

Accessory Minerals – Mica group - Muscovite, Biotite,
Pyroxene

Secondary Minerals – Chlorite, Muscovite, Calcite

Sedimentary Rocks

Sedimentary rocks are also referred to as stratified forms. They are the result of deposition of sediment in successive layers or strata. When a rock mass is eroded, small particles of stone are carried away by flowing water and are eventually deposited in river beds or larger bodies of water such as lakes and oceans, into which the rivulets and streams ultimately empty. Far out at sea these particles intermingle with the skeletal remains of innumerable varieties of organisms. Most limestones and sandstones used by sculptors have been formed in this way.

Limestone

Another important stone largely used for sculptural work all over the world is limestone. Limestone has been used as a carving medium since the beginning of pre-historic period. The Egyptian sculptors' models were generally carved in limestone. The best example of pre-historic limestone sculpture is the Great Mother of Vases of Willendorf, 28000 B.C. - 25000 B.C., and the best sculpture of the early Egyptians is Queen Nefertiti, 1360 B.C.

In the Indian tradition of stone sculpture, the best one is from the Indus valley, The Priest and Male Torso. In the later stage of Indian art most Indian sculptures are made in limestone.

Limestones are composed of calcium carbonate (CaCO_3) and the mineral calcite. Limestones may be physically micro crystalline or coarsely crystalline, generally sandy or granular in appearance. There is a large supply of limestone available in India, which is used for sculptural work. The limestone is usually excellent for making sculpture. It generally carves easily and is quite compact, but takes a very poor finish. Lithographic stone is an extremely fine grained limestone that is quite dense and of homogeneous crystalline structure.

Limestone is generally buff and is the finest variety for grain, uniformity of colour and texture and are generally softer than marble. The colours of the limestone are gray to buff although they may also be cream, yellow, blue, red, green, brown and tinted black. The buff colour is due to the presence of iron oxide. Tinted varieties may oxidise. The blue colour limestone may change to yellowish or brownish buff. The presence of moisture may cause colour changes. Indian limestones are buff and gray colours, fairly soft and easily worked and easy to carve.

Sandstone

Sandstones are fairly porous stones of sedimentary origin, which are marked by compactness and durability. They are composed of fine grains of sand (quartz and silica) bound together in varying degrees of firmness. The harder varieties are almost of pure quality and are frequently used as grained stones for sharpening tools. The pure siliceous stones are the most durable, but they are also the hardest varieties and the most difficult to carve. The important factor in sandstone is determining the degree of polish, because the grains are plucked out in the process. Most varieties of sandstones are quite porous. Their porosity varies between the granules and freestone. Sandstones

are grey, yellow, red, brown, green and black in colour. Two forms of iron oxide are responsible for most of the red forms of sandstone. The presence of hematite (Fe_2O_3) colours the stones red to dark brown. Another iron oxide, limonite ($2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$) causes shades varying from buff to brown.

Sandstone rocks are used mainly for carving caves in India. The Sanchi Stupa of Asoka, 3rd Century B.C., the Yakshi statue of Didarganj, the great Buddha statue at Bhamian Hills in Afghanistan, the Elephanta Caves and the Ajanta Caves are some of the great sand stone monuments.

Metamorphic Rocks

Igneous or sedimentary rock formations that have changed radically during their existence are called metamorphic. The major factors in formation of metamorphic rocks are pressure, heat and chemical reaction. Extreme rocks include quartzite, gneiss, slate, marble and soap stone.

Marble

Marble was more extensively used by the Greek and Roman sculptors than any other forms of stone. It is more softer than granite and has a good white colour. Therefore, it is easier to carve and is more durable than the limestone and other sedimentary formation stones.

Marbles are of metamorphic origin and are the result of the transformation of dolomite or limestone, by various natural forces, such as pressure, heat or chemical action. They are therefore closely related in a chemical and geological sense to limestones. Marbles are occasionally referred to as crystallised limestone. Chemically a marble is the same as a limestone, wherein the carbonates are granular, whereas in a marble they are crystalline. The fine-grained, compact varieties of marble are the best for carving. The fine type of marble consists of an almost pure calcium or magnesium carbonate in crystalline form.

The characteristic of taking polish is responsible for the name, 'marble', which is derived from the greek word 'marmaios', meaning 'shining stone'. The use of creamy white marble by the ancient Greeks started a tradition in the use of fine white marbles for stone sculpture. This practice was continued by the Greeks and the Romans and perpetuated by the extensive use of fine white marble during the Renaissance. The most ancient marble sculpture, is a head from Ardy, believed to be of God Abu Tell Asmar, 2700 - 2600 B.C. (Iraqi Museum, Bagdad). The Romans first worked the famed marble quarries, about the year 283 B.C. and used the marble sculpturally and architecturally in the rebuilding of Rome during the time of Augustus Caesar. Michelangelo, the great artist and sculptor of the Renaissance, used to visit the marble quarries to select choice blocks and used them for his sculptural medium. Its popularity steadily increased during the succeeding centuries until a few sculptors thought in terms of other varieties of medium.

There are three major varieties of marble. They are,

1. Calcite form – Crystallised calcium grains
2. Dolomite form – Carbonate or calcite, crystallised dolomite ($MgCO_3CaCO_3$)
3. Mixed form—Mixture of calcite and dolomite. Pure calcite or dolomite is white. The colours of marble range from a pure white to jet black. Some of the factors to be considered in choosing a block of marble for sculptural use are as follows:
 1. Live stone – a stone that is well preserved or fresh from the quarry and so suitable for sculptural use – identified by striking, when struck with the sculptor's stone carving hammer.
 2. The compactness of block
 3. Freedom of the mass from veins or clouded areas
 4. Uniformity of texture and fineness of graining
 5. Purity of colour

Tennessee marble is an excellent sculptural stone. Geologists divide Tennessee marble into six groups based upon their colours:

1. Gray
2. Faintly pinkish gray
3. Pink
 - a. Light
 - b. Medium
 - c. Dark
4. Fine dark red
5. Coarse dark red and
6. Variegated.

The great masters of world art (sculpture)—Greek and Roman—have used marble as the medium of sculpturing for several centuries. The best contributions of Michelangelo are:

1. The statue of David (Victoria & Albert Museum, South Kensington, England)
2. The Pieta - Madonna and Child (St. Peter's Chapel, Rome)
3. His works at the Medici Tombs in Germany

Another great master was Augustus Rodin whose great statue was Thinker. Calcite and dolomite marbles have been used by the above masters for the above great works of art.

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The Prehistoric “Man” and the “Madras Museum” at the Cross Roads-150th Year

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The year 1851 was the most significant in geological and prehistoric circles both in India and Europe, because it was exactly during that year, 150th years ago, the State Museum at Chennai (Madras) was established with a nucleus of geological specimens. And that year somehow coincides with Putnam's Research, which made the world prehistory, to take over biblical convictions in Europe. Subsequently in 1859, the subject of prehistory was recognised by the Royal Society in London. Leading British geologists and archaeologists, namely Prestwick, Falconer, John Evans, Boyd Dawkins, John Lubbock, James Wyatt, Charles Lyell and Cynl Fox inspired the public by their lectures and initiated further studies in prehistory in Europe.

At that time, a British geologist, Robert Bruce Foote, working in India as an officer in the Geological Survey of India, was influenced by the prehistoric research and activity going on in England and he evinced keen interest to know the evidence and availability of the antiquity of man in India. He discovered the *australopithecine* stone hand axe (Palaeolith) in Pallavaram (near Chennai) during May 1863 and the first stone cleaver tool at Attampakkam (Chingleput District, Tamil Nadu) Kattalayar river terrace during September 1863. Thus, the beginning and the establishment of the Madrasian stone tool industry was strengthened firmly in the Madras Presidency. Robert Bruce Foote took his first collection of stone tools (hand axes, cleavers and scrapers) discovered in the Madras site and exhibited them at the First Congress of

International de Anthropologie et d. which was held in Paris in 1867 and another at Norwich in 1868. He also read interesting papers on his recent discoveries of stone tools in Madras site. He discussed and distributed some of these new tools to the leading British archaeologists, namely Sir John Evans, Sir John Lubbock, James Wyett, Charles Lyell and Cyril Fox for their examination, and they finally confirmed that the tools discovered by Foote in Madras were genuine tools. Subsequently, Bruce Foote discovered prehistoric artifacts from 459 sites all over India including Ceylon and he parted with his collection of 4000 specimens at the cost of Rs 40,000 to the Madras Museum authorities in 1904 to augment the prehistoric collection for display and as comparative source material for research.

Later on, it was V.D. Krishnaaswamy (a student of Mortimer Wheeler and a former Joint Director General of the Archaeological Survey of India, New Delhi) had analysed and classified the stratigraphy of the Madrasian Stone Age Culture, which in due course had a definite line to be followed, by the archaeology students in the field explorations. The Madras Museum was kind enough to receive a sizable number of stone tools collected by him from *Attampakkam* and *Vadamadurai* sites, for study and for reference purposes.

The contribution of Dr. A. Aiyappan (a student of Dr. Malanowski and the first Indian Superintendent of the Madras Museum) towards the collection and study of prehistory and ethnology cannot be easily forgotten. It was he who in 1942 extensively explored the coastal belt of Tirunelveli district and collected a large number of megaliths from *Sangayarasam* site. The first trial digging excavation by the Madras Museum was undertaken by Dr. Aiyappan in 1940 along with his French archaeologist, J. Dubreuil at *Arakkudi* in *Pondichery* and through excavated antiquities, he brought to light the Rome-India trade relations, which were at the zenith during *Sangam* period. In the same year, Dr. Aiyappan excavated two megalithic stone circles

in *Personal Hills in Kodakanal* and the antiquities were added up to the Museum Collections.

The Madras Museum had also augmented its Indian stone tool collection through gifts and exchanges, notable among them are those from Dr. B. Subba Rao (M. S. University, Baroda); Prof. M. V. Moorthy (Andhra University, Waltair); Prof. K.P. Chatteropadhyaya (Calcutta University) to mention a few, at frequent intervals. Apart from these institutes, the museum holds strong stone tools reserve collection received from sites like *Sase Valley*, *Narshala Valley*, *Jakkur* and *Rabri*, *Dhans*, *Gaddalur*, *Nellur*, *Vadumadurai*, *Magar Karana* etc.

Gradually, the stone tool antiquities the world over on exchange basis was successfully effected by the Madras Museum. Among the countries and cultures thus represented are the Rostrocariates, (Dawn Age tools) Ahbevillean and Acheulean (Palaeoliths) and Neoliths of England; the Mousterian and Magdalenean of France; the Palaeoliths of South Africa; the Neoliths of Egypt and Japan; the Tamparisan of Malaya; the *Paiguanan* of Indonesia (Javanan). The Choukoutseian of China (China Man); and the Neoliths of the United States of America.

The collections are not meant only for display purposes alone in the galleries, but also essentially needed for study, research and interpretation leading into scholarly publications. Among the outstanding research studies in the field of prehistory undertaken were those of V.D. Krishnaswamy's palaeoliths of Madras *Kandayar* river terrace, of Yale-Cambridge expeditions to the *Sase Valley* in Punjab and of Father F. P. Manley's palaeoliths of Nellore. Foote, brought together and catalogued the collections of R.B. Beantill from *Mysore*, Stones from *Coimbatore*, C. Cardew from North Arcot and Fawcett from Malabar.

Teaching the subject of prehistory through the Madras Museum had its own innings. In 1901, the Superintendent, Dr. Edgar Thurston was appointed as the Superintendent of the Ethnological Survey for the Madras Presidency, in addition to his

duties. Actually, when the Department of Anthropology at the Madras University was established in 1945, it was chaired, first by Mr M. D. Raghavan, an Ethnologist drawn from the Madras Museum; and due to untiring efforts of Dr. Edgar Thurston, the subject of anthropology was adopted as a post-graduate subject in the University of Madras. It seems that regularly the anthropometric measurements were taken from the visitors now and then by Dr. Thurston in his well-equipped Physical Anthropology Laboratory attached to his office. Till the seventies, the subject and the practical classes in anthropology for the post graduate diploma course were conducted in the museum and teachers, lecturers and students availed this opportunity. It is surprising to know that Dr. Aiyappan, the Superintendent of the Museum, had taken voluntary retirement from the Madras Museum in 1958 to become the Head of the Department of Anthropology at Utkal University, Bhubaneswar, Orissa. In the eighties with the permission granted by the University Grants Commission, certain colleges in Madras city had come forward to introduce the subjects Archaeology - Museology up to B.A. level thro' the Madras Museum. Thus, the B.A. students of the Madras Christian College, the Women's Christian College and the Stella Maris College, Chennai had availed the *in-situ* classes at the Attirampakkam river terrace site, regularly. Considering the wealth of resource materials available in the museum, its high standard of research work, scholarly publications and qualified staff, the University of Madras was pleased to set up a commission to evaluate and declare this great institution of Madras Museum as a centre of research work leading to Ph.D. degree in the subjects of Anthropology and Chemical Conservation in 1996.

Inspite of all these efforts to collect stone antiquities and to popularise the subjects Prehistory and Anthropology still in Madras sites it is not yet possible to trace and establish concrete finds of prehistoric man's skeletal possible remains even in the dense forests of the western ghats. (Except for Bruce Foote's

rewards of the occurrence of a human tibia bone at *Athirampakkam* site). It is a hope of confidence that institutions and organisations like the Anthropological Survey of India or the Archaeological Survey of India or the Museum Association of India in collaboration with ICOM, would take up a resurvey of the castes and tribes of Southern India with a view of receiving and rewriting and updating the seven volumes of Dr. Thurston's "Castes and Tribes of Southern India" with a special aim of combing the dense forests in the western ghats, covering Salem, Erode and Coimbatore hill areas, thereby still undiscovered prehistoric man's habitational sites like the caves, rock shelters, valleys, ravines, river terraces, may be exposed and even may be lucky enough to lay hands on any human fossil find! It is to be hoped that even the Special Task Force can accelerate its combing operations with the help of an anthropologist!

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Some Functions of Stone as Gleaned from Sangam Literature

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The civilisation of mankind had started with the use of stone implements. As a nomad and food gatherer, the prehistoric man with his limited knowledge, used the stones strewn around his rock shelters and foot of the hill, for manufacturing stone implements, that were used by him for hunting and other purposes. Such like stone tools made out of quartzite, assignable to Palaeolithic and Neolithic Periods are available in a number of places in Tamil Nadu. After having expertised in the tool making technique, these people had selected softer stones such as chert, quartz, chalcedony etc., as raw materials for tool making during Mesolithic Age. During the succeeding Iron Age, the use of stone had enlarged to a greater extent. The Sangam literature (3rd Century B.C. - 3rd Century A.D.), which were compiled in the later part of Iron Age, adduce a lot of references about the use of stone in the material life of the people. These literary references were further corroborated by the findings in the archaeological excavations and explorations. Therefore, a pragmatic study is attempted to trace the utility of stone in the Sangam Period i.e. 3rd Century B.C. and 3rd Century A.D. as gleaned from the Sangam works, the results of which are furnished hereunder.

In the Iron Age due to the use of metals such as iron and copper, stone had ceased to be a raw material for making implements. However, stones were largely utilised for a different purpose namely the funerals. Huge (megs) stones (liths) were used for erecting burial monuments. Hence, this culture came to be known

as megalithic culture. Cairn circle, dolmen, cist and menhir are the types of megalithic burials available in *Tamilagam*, wherein stones were exclusively used for its erection.

In literature, often we have also references about *nadukal*, *arukal* and *silukal*, which were perhaps herostones erected in vertical position in memory of a dead person. Since the stone had been in vertical position and offerings (*hal*) been *made* it is referred as *andukalattam* in *marimkalam*. *Takkappayan* lays down six rules as to how herostone has to be erected. They are (1) *Katchi*-probably lying-in-state for sometime of the dead body (2) *Kalkal* - probably to expose the dead body as would be in excarnation (3) *nirpatal*-ceremonial bathing of the bone remains (4) *nadukal*-erection of stone over it (5) *perumbatal* - grand food offerings (6) *sakal* - adoration or worship. All these go to show that for the first time in *Tamilagam* during the *Sangam* Age, the stone was considered as an object of worship, particularly in the funerals.

Existence of *Aravam* i.e. place of worship, is also duly attested by these works. *Pattinattam*(temple for charity), *Vijayattam* and *Vijayamattam*(temples for Indira), *Vakkattam* (temple for *Mariya*), *Urattam* (village temple), *Perumattattam* (temple outside the city) etc., may be cited as examples in this regard. These edifices, ought to be symbolic representation of the gods, wherein as held by many *scholars*, stone was not utilized, since it had associated with funeral customs and practices. Even the archaeological excavations do not incline to provide any evidence contrary on this score. In this connection, it is pertinent to mention here the extensive use of limestone by the *Satanubana* in the neighbouring *Andhras* in the Buddhist architecture that centred around *stupa*, which is yet another form of memorial for *Buddhists*.

All these amplify the fact that stone was used for the erection of memorials and not for the creation of stone icons in *Tamilagam* in the early centuries of Christian era.

Literature also adduce a lot of data with regard to various types of precious and semi-precious stones used for ornamentations. These stones are generally referred in the literature as *kai*.

However its types are denoted by specific names such as *maragatham* for emerald, *manivaru* for sapphire, *paṇṇu* for quartz, *maṇi* for gem and *kai* and *ayiratu* for diamond. Numerous references about coral and pearl are also available. The former is mentioned as *kanki*, *unkaki*, *vali*, *ayir*, *appu*, *ṭaru* and *paṇṇam* whereas the latter is referred as *kai*, *chandravaru*, *ṭarulan*, *aiṭṭilan*, *maṇṇu*, *ṇaṭṭan* and *muttu*. Would the occurrence of more than one name for pearl and coral mean to indicate different classes in coral and pearl? Any how, its sporadic occurrence would endorse the popularity of these stones among the people.

There are also references as to how these stones were converted into beads. These were a class of professionals called *maṇḍiyarṇar* (i.e. one who carves the bead), who converted these stones into beads. Among these beads, good beads suitable for ornamentation were selected. This process of selection is referred as *ṇaṭṭu paṇṇu ṭinṇuṇi*. During this, defective beads were discarded. There were different categories of defects. Defects in diamonds are referred as *kaiyaru*, *kakapadaru* and *ṇinḍu* where as the defects in pearls are referred as *kannu* and *ṭṛakku*. Similarly the defects in coral are mentioned as *kareppataḍu* (a coral bored by an insect). The traders who engaged in the selling of these stones are referred as *maṇḍiṇṇar*. All these stand as testimony to the flourishing stone bead industry in those days in Tamiḷgam. It is very well corroborated by the presence of semi-precious stone beads during the course of excavations in places like *Kaṇṇampattinam*, *Aṇṇamāḍi*, *Kaṭṭakudi*, *Kaḍomani*, *Uraiyar* etc., wherein a number of finished and unfinished beads found in association with raw materials such as quartz, carnelian, agate, beryl, amethyst etc., were collected.

Literature also furnish a number of evidences to the structural activities in those days, the royal palace was known as *manimar kya* and the fort was known as *avadi*, *partur*, *ka*, *rai*, *kattai*, *arai* and *aya*. The gateway to the fort or palace was perhaps decorated with *aravangal*. The townships were categorised and called as *ar* (*village*), *nagaram* (*town*) and *managaram* (*big city*). *Talapatthar* and *Pottinappalai* eulogise the *Puduch* city as having stoned houses (*maadai*). There were also houses with tiled roof (*kura*). These houses had stone platforms at their entrance. It is mentioned as *ari* and it would probably served the passersby to take rest. The kitchen is cited in the literature as *madupali*, *attai*, *attirai* and *adakkalai* while the dining hall is referred as *aravamar sala*. Besides references to bathing ghat (*kalar*), granary (*katti*), art gallery (*Chitramandapam*), dance stage (*talukkalavan*) place of study (*path*) underground chamber (*patram*) and market (*argam*) are also available in the works. All these emphatically amplify that there was a well-developed structural activity. In this connection it is pertinent to mention here, that majority of structural remains unearthed during the course of excavation in Tamil Nadu were constructed out of bricks. In the absence of sufficient material evidence, the utility value of stone in the construction eludes further study.

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Stone Sculptures of Government Museum, Chennai

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Art in India was never dissociated from other aspects of life from other disciplines. This is very much evident from the literary and archaeological evidences throughout the history of India. Sculpture manifests the vision of wholeness through a methodology of impersonation. Indian figurative art is not portraiture of the specific. Each image is an embodiment of a dominant abstracted impersonalized state of mood in a given stance or pose evoking stillness and dynamic movement together. Each is a complete world in itself. Stone is used as a medium of art in India since the time of Asoka (271-232 B.C.).

Tamil Nadu, as elsewhere the underlying basis of sculpting rocks or carving relief sculptures was that every stone boulder or rock had cosmic vitalities running through it was so much of uncarved sculpture. Actually, this concept of energies running through stone was begun to be realised by the Buddhists. Indian architecture whether the stupas or the temples or the mosques are an archaostation of multiple forms flowing out of and flowing in to a centre.

The stone sculptures are the most permanent arts frozen at a moment of time for posterity. They are shaped and formed in the act of creation, live for the moment, the specific duration. Each part of the relief or each macro-unit of the human figure plays its role – the eyes, nose, ears, face, torso and limbs and each physical gesture singly and in combination is suggestive of an inner meaning, which in its totality suggests an impersonal emotion and thus evokes a transcendental heightened experience.

It seems that the *Pallavas* were feudstones of the *Satavahanas* of Andhra. They visited the rocks of Mahabalipuram and began to explore the possibilities of creating buoyant shrines and figures in relief. The myriad-minded Mahendravarman's imaginative gesture, genius conceived cosmic-earthly creations from the huge boulders. But it was *Mamalla*, the grandson of *Rajasekha*, created the paradise of marvels hewn from boulders. The *Pallava* sculptors surpassed themselves in creating the *raihar* out of monolithic granites. "The transition from sculpture as architecture, to the structural temple, where the carvings adorn the temples, was brought about in Kanchipuram, under *Rajasekha Pallava*, during the first quarter of the 8th Century A.D."

The position occupied by the Government Museum, Chennai made it one of the pioneer institutions in the whole world. There are a lot of South Indian stone sculptures in its collection. The sculptures of the dynasties that ruled over the southern part are chronologically arranged at the entrance of the Stone Sculpture Gallery, which enable the visitors to understand them properly:

The Buddhist Sculpture Gallery houses some of the earliest specimens of the art in the form of sculptures, architecture and inscriptions, such as sculptures from *Amarnath*, which are most probably the earliest existing sculptures of South India dating from about 200 B.C. *Amarnath* is situated a little over twenty miles from *Guntur* and having now dwindled into insignificance is more a village than a town. But once it had its day of glory.

The importance of the site of the *Mahadevi* at *Amarnath*, known locally as *Dipaladine* (hill of lamps) was realised by Col. Colin Mackenzie as early as 1797. A year earlier, a local *Zamindar* had changed his residence from *Chintapalli* to *Amarnath* and laid foundation of the modern township around the *Amarnath* temple. Many people, at his invitation, settled in the area and the building activity that ensued there after led to the spoliation of several mounds yielding large sized bricks and limestone slabs. The *Dipaladine* didn't escape the *Zamindar's* eyes. It was ransacked



View of the Amarnath Gallery

for suspected treasures and also perhaps for building materials. At the time of digging some sculptured slab came to light and the news reached Col. Mackenzie, who at once paid a brief visit and assessed the potentiality of the mound. After his visit several European scholars visited the site and recovered many sculptures and some best pieces were sent to the British Museum, London. 299 pieces were brought to Chennai Museum and were exhibited in the gallery.

Amarnath stone sculptures were made of recrystallised limestone.

Most limestones are made up parts of the skeletons of sea animals. Limestone usually consist of the same three general groups of materials as sandstones, dentous particles, fine-grained matrix and cement all of which may be the mineral calcite.

1. The model of the *Mabasta* after Percy Brown, was made in plaster of Paris and exhibited at the entrance of the gallery.
2. A view of the Amarnath Limestone Sculpture Gallery.
3. A coping fragment garlands are supported by dwarfs. One of the dwarfs, quite dull looking with elephant's head without its proboscis and tusks.

This figure, Dr Ananda K. Coomaraswamy had pointed out the earliest approach towards the form of Ganesa. Hence, we have the earliest representation of the parent of the later iconographic form of Ganesa with a prominent paunch, short and stump, limbs, elephantine head and ears. It appears almost cut off and foreshortened front view of his head without a trunk (proboscis) is so superb that it baffles one to know how the sculptor managed to imagine and such a figure, which is datable to 200

- 100 B.C. Indeed, the creation of so curiously blended figure, a stroke of genius on the part of the sculptor, who was also a stroke of luck for his model. We have no doubt that the image itself contributed largely to the fame of the god.

Subjugation of Naliger

The Buddha had a cousin called Devadatta, who impelled by sheer jealousy wanted to do away with the Buddha. Having failed in many attempts, Devadatta conspired with the palace mahouts and succeeded in letting loose the fierce elephant, Naliger to attack him. But the fierceness of the animal vanished at the sight of the Buddha before whom it crouched in all humility. The umbrella and architectural features such as the gateway, towers and balconies are noteworthy. It belongs to about 150 A.D.



*Subjugation of Naliger, (Limestone)
Amaravati, Andhra Pradesh*

Casing Slab



Casing Slab (Limestone) Amaravati

It is fortunately very well preserved and shows a typical *stupa* flanked by *abornachakra* pillars and with a frieze at the top. A railing surrounds the *stupa*. Three of its gateways are shown. The plinth, pillars, crossbars, coping stones and guardian lions are shown clearly. A *permakalasa* is shown on either side of the gateway. The drum, *gate* pillars and the casing slab with

sculptures is shown behind the rails. A *kirtimukha* surrounds the dome with umbrellas at its two corners. *Devas* and dwarfish *yakshinis* adorn the *stupa* with offering in *traya*.

The *dharmachakra* pillars on either side stand behind empty thrones suggestive of the *Buddha*. Above the wheels, dwarfs and *devas* play on musical instruments. The frieze at the top shows three important scenes from the life of the *Buddha*.

Sajata Feeding the Buddha



Sajata Feeding the Buddha (Anuradhapura) Anuradhapura

Sajata was the daughter of *Janani*, a rich man of *Uruvela*. She promised rich offerings to a *Nigrodha* tree, if her wishes were fulfilled. Things happened as she prayed for. She accordingly made preparation to fulfil her promise. When the *Bodhisattva* went to the *Uruvela* forest and sat under the *Bodhi* tree, the surrounding place was

illuminated. Having heard of this, she went to him offered him the specially prepared porridge, which he accepted.

In the sculpture, the headless *Buddha* is seen seated on a throne and *Sajata* is standing with a jug in her hand. The porridge, *Sajata's* son is also seen here. It belongs to about 200 - 250 A.D.

Slab with a Drawing

Slab with incised outline of seated figure opposite the former. It is important as it is showing the method of carving. It belongs to about 200 - 250 A.D.

The sculptures of the Tamil country dating from the 7th Century A.D. are simpler in treatment than those from the *Deccan*. "In the lines of its figures, in its treatment of eyes and the absence

of canopies, these sculptures resemble the *Amavasi* period, but it has more rugged strength than the *Amavasi* and *Capta* sculptures". The poses of the figures are treated less heavily than in the *Chalukya* specimens.



Slab with a Drawing (Limestone)
Amavasi

Vishnu's crown, which is based on the earlier type of *Sakra's Kirita*, is quite elongated in the *Palasa* period and continues this shape right through. The earlier short cylindrical *kirta* of *sakra*, as seen in *Satrahara*, *Kuthana*, *Gandhara* sculptures at *Amavasi*, *Matara* and *Taxila* respectively, is transformed into a long cylindrical type unlike the cone-shaped *kirta* of other deities. The face is slightly taller than broad, with flat nose and double chin. The front of the torso is almost flat. Despatches tend to be heavy. Emblems are naturally held in the hands or just about them and are without flames. The sacred thread is ribbon like with a broad fastening over the left breast.

Ganasa (Eastern Chalukya Period)
Brihasati, Andhra Pradesh.

Seated with two hands with *modaka* in both the hands. His trunk toying with the sweetmeat in his right hand. This is a superb representation of the God of Eastern *Chalukya* period in a real elephantine face. The size is amazing but it is weather beaten.



Ganasa, (Granite) Brihasati

Ardhanarisvara (Early Chola period)

Thiruchanaimallur, Tamil Nadu.

Standing in *abhaya* pose, this *androgynous* image is a representation of marvellous execution of art of the

"சென்னை முகாமத்து நகரத்து
ஆராய்ச்சு முது அது சென்னை
கலைகளை நகரங்களுள் முன்னால்
மற்றதும் அகலமால்
கலைகள் அகலமால் நிறைந்தவை
நிறைவு நிறைவு கூட
சென்னை நகரத்தின் நகரங்கள்
நகரத்து மன்றங்கள் சென்னை"

This sculpture under reference is greatly admired by Prof. K. Nilakanta Sastri in his "Colas". Here the *netra yugapante* is beautifully done. The stone is a granite variety.

Durga

Cuddalore District, Tamil Nadu

Standing elegantly on a buffalo's head in *abhaya* pose this Durga is a classical example of *Vijayanagar* period in green schist. This figure tends to be formal with elaborately conventionalised draperies. The face is somewhat expressionless with prominent nose and chin. The abdomen is rounder than the earlier period and droops forward. The navel is overemphasised by horizontal and vertical rays.

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Durga
Cuddalore District

Amaravati at the British Museum

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The British Museum's collection of sculptures from the Indian subcontinent is world-famous for its great size and the enormous variety of wonderful material that it contains. Great pieces from Buddhist Gandhara in the North West, a superb array of stone and metal sculptures from Eastern India of the Pale period, many unique and wonderful things from Central and North India and a small but very distinguished body of sculptures from South India in both stone and metal characterize this collection. What makes the British Museum's Indian holdings probably the greatest outside the subcontinent itself, however, is the large group of limestone carvings from *Amaravati* that have been its glory since the year 1860.

Excavated in the 1840s by Sir Walter Elliot, these pieces (with a very few from the group removed by Col. Mackenzie) came to the UK in 1860 where they were placed variously by the East India Company Museum (later the India Museum) in a number of situations in London. With the abolition of that venerable institution, they found a final resting place in the British Museum in 1860 and from that year to the present, whether on display or not, have formed the greatest single coherent collection of sculptures from a single Indian site, outside India itself. When they came to



*The Amaravati Sculptures in the Great Saloon of
the British Museum (1860-1919)*

the British Museum, the *Amaraat* or the Elliot marbles as they were then called, soon found a home on the wall behind the landing of the Great Staircase just inside the front entrance of the British Museum. Mounted behind glass-fronted cases with mahogany surrounds by the then Keeper of Antiquities, Mr A.W. Franks, with the assistance of Sir Walter Elliot himself and James Fergusson, who wrote about the sculptures so eloquently, the *Amaraat* marbles stayed in place until the beginning of the Second World War. These great sculptures were for some sixty years at the heart of the Museum and did all visitors to the building see the first things. Their influence in design terms was considerable. The *Amaraat* sculptures were in their own way of influence too and elements from their complex reliefs can be seen at certain places in England, notably at a country house called Compton near Guildford in Surrey outside London where a mortuary chapel, dedicated to the memory of George Frederick Watts, a great painter of the Victorian period, incorporates *Amaraat* decorative motifs into its otherwise Celtic and Art Nouveau interior. The *Amaraat* sculptures were mounted in the Museum in a position anterior to all the other great works of art and culture it held.

With the coming of the Second World War in 1939, it was clear to all concerned that the *Amaraat* sculptures had to be dismounted and put in a place of safety. They were dismantled by Basil Gray, Keeper of the Department, and placed out of harm's way in basements deep in the Museum. Out of sight for the duration of the war, the *Amaraat* sculptures remained secluded for a further period until it was again possible to consider re-mounting them in a public place in the Museum. They were established in an area of the Front Hall, just to the left of where the old entrance to the famous Round Reading



*The Amaraat Frieze
Housed in the Front Hall
of the British Museum
(c.1890)*

Room of the British Museum used to be, the railing erected, free-standing and self supporting. Panels from the drum and from the dome of the ancient *stupa* at *Amaravati* were mounted on the walls of the Front Hall behind the railing. Parts of the sculptures lost in antiquity were made up with cement additions and infills to permit all this reconstruction to stand securely.

It did indeed stand and remain in place for a period of about three years until, in the early 1950s, a very unpleasant phenomenon was noticed. Small, almost dust-like fragments of stone were noticed to be dropping off the surface the 'marbles'. The cumulative effect of this erosion over time was going to cause very serious damage to the sculptures if action were not taken at once. The Museum authorities called our Research Laboratory to investigate this process and discovered that it was the result of changes in the stone itself, brought on, in simple terms, by the contact of the stone with the damp and heavily polluted climate of London in those times. At the request of the British Museum, this process was investigated at the same time by colleagues in Madras and the same conclusions drawn. In simple terms, certain salts in the body of the stone combine with moisture and sulphurous pollutants in the air to form larger crystals than are present in the composition of the stone itself. These crystals act to push off tiny particles of the surface of the stone. Further, the sculptures were themselves cut in antiquity with their 'bedding planes' (i.e. the 'grain' of the stone) arranged vertically for ease of sculpting. This vertical arrangement serves now only to



*The Bodhisattva Manjushri (British Museum 1860.7.9.123).
Photographed in 1859 by Captain*

assist any process of erosion of the stone surface that may be taking place.

The sculptures had resided on the Great Staircase of the Museum for sixty years, kept behind glass in cases so accurately made that they acted to produce a sealed atmosphere, protecting the stones for all of that time from any damp and pollution damage. It is clear now that their surfaces are, in many cases, different from the condition in which they were originally found and then, before they were sent to London, photographed at Madras and published in the 1830s by Captain Linnaeus Tripe. These differences in surface quality are certainly due to contact by the *Amaraṇaṭ* limestone with the atmosphere of London during the period 1860 to 1880, before they came to the British Museum.

A basement chamber dedicated to the *Amaraṇaṭ* marbles was constructed, the arrangement in the Front Hall of the Museum demolished and the sculptures taken to their new home. The atmosphere of that room was conditioned by a complex air cleaning and drying process. All sulphur-bearing chemicals in the polluted ordinary air of urban London were removed and the air in the chamber de-humidified to a constant optimum level of 45%. In this condition the *Amaraṇaṭ* collection at the British Museum remained for nearly fifty years, safe, seen by a handful of dedicated students, scholars and a few lucky private visitors, but entirely out of the eye of the general public. The period of the 1950s to the early 1990s was a sad, rather lonely time for the *Amaraṇaṭ* collection though the Department of Oriental Antiquities and, the Trustees of the Museum constantly expressed the desperate need to get these precious sculptures back on exhibition. What always stood in the way of this re-exhibition was the absolute requirement for replication in any new gallery dedicated to these treasures of the relative humidity-controlled and pollution filtered atmosphere of the then current *Amaraṇaṭ* basement. Air-treatment of a space dedicated to these pieces would have cost a tremendous amount of money and,

furthermore, there was never during that time any space available to the department for such a display to be mounted.

The New Amaravati Gallery

In 1989/90, plans for the complete refurbishment of the Oriental Gallery at the British Museum along with a total re-organisation of the permanent display of the Museum's Indian and Chinese Collections were started. With this great plan, a scheme to redevelop the West End



The Glass Wall Separating the Asian Studies Gallery of Amaravati Sculpture at the British Museum from the Rest of the Permanent Asian Display in the Sir Joseph Flaxman Gallery of Oriental Antiquities

of the Oriental Gallery for a permanent exhibition of *Amaravati* sculptures was developed as well. The first requirement of this new *Amaravati* room was that it be air-conditioned to the standard just described. Such a need could only be achieved by the installation of an effective complex of machinery capable of handling all the processes necessary for the task and by a means of isolating the *Amaravati* space from the rest of the gallery, itself as long as a football pitch, though not nearly as wide. The latter task was achieved by the construction of a huge glass screen separating the *Amaravati* room from the rest of the space to provide an area controllable in atmospheric terms.

This new scheme for the *Amaravati* sculptures required vast finance to cover the very considerable costs of the project. It was hoped from the beginning of the fund raising for this area that a grant from a grand Indian source might be forthcoming to support work on a project that was probably, in the world outside the Sub-continent, the most important display of Indian sculptures possible. In the end, funds from the Japanese

Newspaper Company, the *Asahi Shimbun*, were secured for the purpose and our plans for the gallery were put into place. This area is now called the *Asahi Shimbun Gallery of Amaraat Sculptures*.

Our first purpose was to provide an environment for the collections from India, South East Asia and China worthy of the superb objects displayed in the gallery and of the world importance of the cultures they reflect. The walls of the gallery are covered not with paint or paper but with pure gold-leaf lending a unique splendour to a place containing some of the great artistic achievements of mankind.

The British Museum believes in placing these objects in their ancient context if possible and to offering an explanation of them as far as can be achieved. From the beginning, it was clear that the *Amaraat* sculptures were not going to be exhibited simply as examples works of ancient art.

The British Museum recognises the need for explanation and interpretation in its work both in permanent galleries, temporary exhibitions, and in its published, scholarly work. The grand displays reflect this thinking in what is called the Hotung Gallery, named after the main benefactor of this great room, Sir Joseph Hotung. The Indian collections in the Museum, both sculptural and metal, mostly illustrate the religions of India. Religion in general terms is practised by virtually all the people of India and for that reason, Indian religions are used in this room to assist in explaining a part of what is important and unique to India.

The gallery begins with a short historical background leading quickly on to an explanation of the great ancient religions of India: Buddhism, Hinduism and Jainism. The principal deities are illustrated in sculptural form, along with explanations of religious ritual, iconographic principles, the temple, *stupa* and relics, pilgrimage and festivals, costume, the origin and development of ancient Indian writing and many more such didactic matters. Along with these rather thought-provoking issues, using a wide

range of Indian material from many places and periods, are a series of grand regional displays (ancient Kashmir, Eastern India, Orissa, South India, Sri Lanka and the cultures of Southeast Asia) all illustrating issues of religion germane to our main purpose.

The display of the *Amarnati* marbles in our new gallery follows this view precisely. The *stupa* is reconstructed in schematic form. Some of the most important pieces such as railing, balustrade and certain cross bars are set high up on the summits of the rail pillars themselves, making access to them less easy than if they were displayed individually at ground level. The sculptors at home were not made to be works of art.

The *Amarnati* sculptures in this new arrangement become, therefore, much more than just a collectivity of art



The Display of Amarnati Sculpture in the New Permanent Gallery at the British Museum



The Railing of the Amarnati Stupa as Displayed in the British Museum

objects. In the monumentality that is expressed in this room, they become the equal of anything that was produced in the rest of the ancient world. The western world is fed from the cradle on a diet of the art and culture ancient Rome, Egypt and Mesopotamia and so these great ancient cultures have dominated the old museums of the world since their various foundations. What the British Museum lacked during the war years and in the time from the early 1950s to 1992 was the Indian alternative, a rare phenomenon that was present in the old, pre-war Museum in the flat



Dome Slabs from the Amravati Stupa Displayed in the British Museum

at all.

In the middle of the *Amravati* room is a great plinth, which supports the remains of part of the railing complex. To the west of this feature is a series of dome slabs and pilasters mounted on a deep wooden box in imitation of the supporting platform of the original building. Above this arrangement on the west wall of the gallery are a series of 'dome slabs' in imitation of the sculptural system at the base of the dome of the old *stupa*. Here and there in the *Amravati* room are pieces of spare sculptures and on one wall is a reconstruction of a railing set of an earlier period.

Mounting and Conservation

With the problem of control of the atmosphere in the new gallery settled by the installation of a modern system of air conditioning and pollution control, the main issue for our mounting and

displays on our Great Staircase but which put Indian art and architecture physically before that of the classical Mediterranean world creating a kind of artistic or cultural hierarchy not valid by any real measure of such matters, though better than none



A Section of an Early Version of the Railing from the Amravati Stupa as Displayed at the British Museum



*The Iron Rack Used to Support the
Amarutah Railing Arrangement as
Display at the British Museum*

conservation specialists at the British Museum was how to transport the stones from their old quarters to the new gallery, how to mount them in place and how to ensure their permanent and stable positioning. For the railing arrangement in the middle of the gallery, a massive iron rack was designed. It consists of a series of uprights and crossbars all designed to hold up the ancient limestone parts of the railing. As the fragments of the railing were put in place, the iron crossbars and all the other paraphernalia of mounting stone were bolted into position. The tallest of the rail pillars was given its own iron module, which was used to transport the piece from the old basement and finally to act as its permanent frame in the new railing display. Special ski-like iron slides were devised to allow this piece to be moved easily in its iron frame in the upright position into place in the rail arrangement. All these heavy stones were hauled up from the lower floor of the Museum to the new gallery via a huge trapdoor cut in the floor of the gallery. This opening is now sealed up but if for any reason pieces from the gallery need to be moved away, it can be used again for the same purpose.

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*The Iron Module Used both to Move the
Tallest of the Amarutah Railing Pillars the
British Museum and to its Display*



The Amaravati Gallery at the British Museum During the Mounting of the Sculptures

The mounting of slabs on the walls of the gallery required careful planning of the final placement of the pieces in drawn form. When it was clear where each piece was to go the wall was drilled and strengthened by installing hard concrete, in the old and rather weak structure of the brick wall, into which were set iron corbels, which would support the stones when they were in place. The floor of the gallery was found to have been made from a composition consisting for the most part of clinker and which would not tolerate any excavation into it for any purpose. Such an invasion of the floor would have resulted in it

being dangerously weakened. The pillars from the great railing at *Amaravati* are mounted directly on to the floor of the gallery, therefore. They are, as a consequence, higher in configuration than they were in their original position. This cannot be helped. The arrangement of the scenes in this gallery is schematic in any case and the issue of railing height needs to be seen in that context.

During the mounting of the sculptures, the gallery was, quite literally, filled with scaffolding in order for the sculptures highest up on the walls to be placed in position first. A forklift truck was lifted up to this level as well and used in the mounting of the highest slabs. With these sculptures in place (the dome slabs in particular) the scaffolding was gradually reduced and the pieces closest to the floor installed. This hugely delicate and complex process, requiring a very serious planning period long in advance of the work itself, was achieved without even the slightest damage to the fragile stonework we were mounting. In such a process, it is quite clear, planning of the task is at the heart of the

successful realisation of the project. The planning for our new gallery in its entirety certainly took the greater part of a year and the rebuilding and mounting itself more than a further year. The excellence of the results, however, certainly justifies the massive investment in time spent planning for them.

Cleaning and conservation of the sculptures was in the main a simple matter. No chemicals were used in this process. For practically all the cleaning work that was done by our stone conservators, water and cotton swabs were the only equipment. The stones were dusted, of course, and where old cracks and joints needed mending that work was done up to the highest modern standards with the notion of the reversibility of any apparently permanent process being uppermost. One brilliant piece of work involved the copying of the side of the face of one of our lions in order to provide a replacement for half of it lost in antiquity and cut flat and sharp in stark contrast to the remaining profile. The intact side was copied in a rubber-like compound, a cast taken in a resin, that attached to the head and then carefully painted to form a complete face.

Continuing protection of the *Asarsuul* marbles involves a fairly simple set of issues. The relative humidity and air pollution levels must be kept to a standard established long ago by our scientists. Monitoring devices take care of those issues. The British Museum had a different experience with a complicated computer-dominated 'building management system' installed to control air conditions in our Japanese Gallery complex in the late 1960s. It was so sensitive and so technically complex that it had to be reorganised and heavily scaled down in complexity. It now works



The Reconstructed Head of One of the Guardian Lions from Asarsuul (British Museum 1880.7.5.105) on Display at the

admirably. When the new *Amaraot* air-treatment plant was being planned, engineers doing that part of the work were asked to design a device probably no more complex than that available in the 1950s, though with a few essential modern features bringing the system technically into the late 20th Century. With this sort of relatively simple arrangement in place, working steadily now for nearly ten years and subject to constant monitoring, the system has proved to be a complete success.

An issue most threatening to the long life and preservation of the *Amaraot* sculptures is that of protecting their delicate surfaces from the touch of visitors. Measures have been taken in the British Museum to prevent human touch with the sculptures. Low bronze railings provide excellent protection for surfaces that can be kept beyond arm's length. When anyone, including Museum staff who frequently wave their arms about as they explain the arrangement to visitors, breaks the electronic beam installed between object and visitor a loud alarm sounds and a wander or guardian rushes to the place and the person prevented from touching the stone. The sound of the alarm is enough in the overwhelming number of cases to scare off even the most foolish of visitors.

Amaraot in the Modern British Museum

With the addition of the *Amaraot* stone sculptures to the Honing Gallery of Oriental Antiquities at the British Museum, we have restored to our presentation of the art and culture of India one of the most convincingly grand arguments in favour of the importance of India in ancient times. Our pride in this gallery, dedicated to the use of religious artefacts and architectural elements in stone for this purpose, is that it is now used as well for a wide range of creative and highly popular educational purposes.

The *Amaraot* sculptures are, in a real way, reverting now to something like their original purpose. They no longer adorn the now ruined great *stps* at *Amaraot* but they do, in their

iconographic and narrative content, set in the modern world as brilliant teaching and interpretative aids. The labels and information panels in the *Amarnath* Gallery contain basic information about the history of the discovery of the stones, the architecture of the *stupa*, the various components of the complex itself and a basic explanation of the iconography and chronology of the sculptures. With all this material a new catalogue of the *Amarnath* collection appeared at the time of the opening of the gallery nearly ten years ago. In this work, the entire collection is illustrated for the first time. *Amarnath* is now freely available in London in the public exhibition and the entirety of the British Museum collection accessible to the outside world via the catalogue. Huge numbers of visitors see the *Amarnath* room every year and with people from Buddhist countries it is an essential part of any visit to the British Museum. The next step to be taken in connection with our holdings of *Amarnath* material is to arrange for the digitisation of the sculptures and their placement on the internet and so completely available to all people with access to that facility. We are heavily engaged in this process at the British Museum in connection with our holdings of paintings from the Buddhist caves at Dunhuang. They are superbly reproducible in this form and small details of these paintings can be magnified hugely, just as would details of the *Amarnath* sculptures, if done in this way. Our aim is to provide as complete access to this body of material as can be achieved. All lovers of great art, the people of India and the rest of world need a clear route to at least visual access to the British Museum's *Amarnath* collection, an aim genuinely achievable in the short term.

Curators frequently take people around the *Amarnath* Gallery just as Buddhist monks in ancient times may have done with pilgrims to the *stupa* at the height of its glory. They explain the history of the *Amarnath* School of Sculptural Art along with the principles and symbolism of the Buddhist religion, the traditions and myths attached to the life of the historical *Buddha* and his previous lives and many other issues. People are drawn to this

new display by its capacity to teach them about the Buddhist tradition of art, architecture and religion and they are excited as much as anything by the novelty of seeing sculpture of exceptional beauty and quality in the context of what we call a 'world museum'. It is a matter of great satisfaction to the British Museum that India finally takes its rightful place, via this gallery, in the great pantheon of the architectural achievements of the cultures of the ancient world, examples of all of which are accessible in the rooms of the British Museum.

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Care in Display of Stone Objects

N. Harinarayana,

Formerly Director of Museums, Tamil Nadu

The letter from the Commissioner of Museums inviting papers for the Special Volume on Conservation of Stone Objects in museums expresses concern about the condition of the sculptures in the *Amaravati* Gallery of the Museum and attributing it to the method of display employed in 1878. Even at that time, scholars expressed serious reservations about embedding the sculptures in walls and the use of Portland cement for fixing them to the wall. Dr. Burgess, archaeologist and later Director General of the Archaeological Survey of India, made a scathing attack on the display method used. The sculptures should have been kept inside glass cases as had been done in the British Museum, he said. Encasing the sculptures in Portland cement was wrong for they can never be extracted from them. "Few museums have received so important a collection of sculptures, none has showed itself so unworthy of such a granton and vigorous abuse of such a trust".

Dr. Bidie had the task of defending himself to Government. "The slabs were so heavy and brittle in the opinion of the Consulting Architect to be erected without fitting up the interspaces with cement", said Dr. Bidie. He defended himself further: "In fact, scientific visitors from various parts of the world have already, not once but often, expressed their approval of this collection as now stands". Dr. Bidie's views prevailed with the Government.

Since then, the recent reorganisation of the *Amaravati* Gallery in the British Museum has stirred fresh thinking about the display of these sculptures in the Madras Museum. In the 1878 preservation, a slightly curved masonry wall was built to simulate

the wall of the original *stapa* and many slabs were fixed in position, which they might have occupied conjecturally in the original *stapa*. It is an attempt at recreating the context of the sculptures.

Display of stone objects depends on several of their characteristics as material. The first characteristic is that most of them are heavy and big. Small objects of stone are few and far between and whatever small sculptures exist are those made of semi-precious stones. These have to be kept naturally inside showcases. One method of keeping them outside showcases and without being embedded in walls is to keep them on wooden pedestals the top of which is suitably cut out to make a proper fit for the sculpture. The pedestal is also to be suitably strong and heavy to carry the heavy sculpture on top. This method has been used in several museums.

But, for heavy and huge sculptures, which are above 5 feet in height or width or length, there seems to be no other way, except to build low masonry pedestals and fix them with cement, care being taken to see that the cement mix does not spread to any decorations on the sculpture. Whether the sculpture is to be fixed against a wall or mounted in the middle of the gallery in a random arrangement that enhances the appearance of the gallery is our choice. A mix of small stone sculptures on wooden pedestals and a few huge stone images on masonry supports, tastefully spread out, can make the gallery attractive.

Another characteristic of stone objects is their comparative stability against degradation. Even metals are more prone to deterioration than stone. Chemically most stones are made of co-ordinate compounds, which are not easily decomposed chemically. The exceptions are marbles and limestones, which are easily affected by acidic substances. Stone objects kept indoors in galleries are even less liable to deterioration than those kept outdoors, where regular changes of temperature, constantly blowing winds and rainfall during the rainy season causes surface

damage called weathering. In a survey of marble in the Saha Jung Museum, the present author noted three types of deterioration of the stone exposed to the atmosphere: a roughening of the surface accompanied in some cases by the formation of mat opaque patches, formation of tiny pits all over the image and development of large polygonal cracks. It must however be mentioned that most of these marbles were exhibited in the open or in open verandahs at spots near the open end of the verandahs. What they were showing were symptoms of weathering softened by the fact that they were only partially exposed to the sky and the elements.

The problems of stone objects kept fully indoors are much less than those objects in the open. Temperature changes are minimised. Wind effect is almost niled out. Pollution is lessened. Biodeterioration is almost nil. Dust is the only large problem found by them. In a tropical country like ours, fine dust gets into the interior of rooms and settles on exposed stone objects. Cobwebs springing up due to spiders, which have a way of their own in thriving and weaving their webs.

It is in countering these factors that care should be exercised in display of stone objects. Since dust is a big problem, the display room should be without open windows. If there are windows, they may be glazed to let light in and keep dust out. Then the room may become sultry and a system of installing fans should be devised so that there may be air circulation in all parts of the room. Diffused even lighting may be installed for viewing the stone objects. Excessive humidity during the rainy season may be reduced through dehumidifiers.

It is in the display of stone objects in the open that utmost care has to be taken. Here the objects are exposed to all the elements all the time and take all the problems, which monuments face. Since these objects in a museum would be moved about, it is best that the space above them is covered and that they are not directly in the open unless it is inevitable. A cover above them

reduce the effect of damaging factors a great deal, but still utmost care has to be taken to see that they are free from the effects of pollution and biological agents like algae, fungi, lichens etc. The spots for installing the stone objects should be so selected that direct sunlight does not fall on them or falls for the least time. Regular cleaning of the objects should be done, especially for removal of dust and cobwebs. In the case of objects exhibited in the open, a suitable surface coating may be given. After considerable study of preservative coatings for sometime in historical monuments in Thailand, Josef Riederer and Prasertset Chompemert concluded that "the combined application of ethyl silicate and hydrophobing materials, either by commercial mixtures of these compounds or by a consecutive application of ethyl silicate and a hydrophobing material produces a durable protection against weathering". Poly methyl acetate solution in a mixture of toluene and acetone, which had been largely recommended for a time as a coating for stone objects has not been found so effective as expected. O. P. Agrawal, Ashok Kumar Pandey and A. K. Verma in a paper in the restoration of statues and marble canopy, state that for all the objects, finally a protective layer of silicon resin was given. Ethyl silicate is valued as a protective coating of stone objects because it is decomposed by the influence of humidity and subsequently gives off silica, which acts as a consolidant for the stone on which it is coated. So ethyl silicate can be combined with silanes permitting a consolidating and a hydrophobing treatment by just one application (Riederer and Prasertset). Manjra Singh *et al* observed that the mechanical strength of khondalite samples increased considerably in the case of their treatment with silanes.

Considering all these facts, a mixture of ethyl silicate and a silane would be a good protective coating for stone objects. Franco Piacentini enumerates in his paper the characteristics expected of a protective coating for a stone object: "lack of colour, chemical stability, stability to ultra violet irradiation and to heating, must

be insoluble in water and usual organic solvents, provide treatments permeable to water vapour and gases and also reversible. Materials today in use for the consolidation of stone are: ethyl silicate, alkyl alkoxi silanes, acrylic resins, epoxy resins. Ethyl silicate is the oldest and is still widely used. It is effective and very stable. Due to the formations of silica as aggregating agent, it is not however ideal for use on carbonatic rocks".

Various factors, which are at the back of display of stone objects, have been enumerated. Stone objects inside rooms are comparatively free of problems of deterioration. Embedding in wall has been discounted as a process of display for reasons of deterioration, which the wall and its humidity may induce in the sculptures secured in it. Air conditioning has not been suggested, as it will not be effective unless properly carried out and is expensive to boot. Stone objects can do without it mostly. If air-conditioning is still to be done for the sake of showing our concern for masterpieces, it should be thorough air conditioning, not the room conditioning variety, which merely draws air from outside, cools it to the temperature set and blows it into the room. Good house keeping methods are essential for any stone sculpture to prevent accumulation of dust, cobwebs and salt blown in with the air.

The question of the colour of the walls of the pedestals and of any background in showcases have to be thought of carefully. Pastel colours, colours that do not obtrude on the eye when viewing the sculpture, are to be selected. A lightly textured, a light coloured cloth may be good background material against which the small sculptures are to be fixed.

It is not unusual to have big stone sculptures installed in sculpture galleries. In that case, the sculptures are to be mounted on masonry, the underside of which is to be covered with waterproofing material to prevent seepage of water from the ground. Such sculptures are to be given protective coatings as given to monuments to keep these in good condition.

Care has been taken to see that only the display aspect of stone objects is mentioned though inevitably conservation facts have also crept in. Sculpture in stone has a certain presence about it, which fascinates one and care in displaying it should bring this out best.

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Medieval Monuments of Pudukkottai: Status of Granite

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Pudukkottai lies between latitude $9^{\circ} 50' - 30''$ N and $10^{\circ} 44''$ N and longitudes $78^{\circ} - 25' - 5''$ E and $79^{\circ} - 46'$ E and is bounded by *Thiruvannamalai*, *Thayyasar* and *Sirugudalur* districts¹. The district has small range of hills in many places. These rocky hillocks are *archaean*, a hard rock, which are formed between 3000 - 600 million years ago composed of gneiss, schist and crystalline metamorphic rocks². This type of stone is the so called granite. The term granite is more general in India, for all crystalline rocks as long as they are tolerably compact, granular, crystalline and speckled in colour. Granite had been principally composed of quartz, feldspar and mica, either as a ternary compound of these minerals or as binary compound of two of them³. The granite in *Pudukkottai* is pink or black in colour. Robert Bruce Foote would say the stone in the hillocks of the district is banded micaceous granite gneiss variety⁴. Granite is extensively used in the construction of temples in South India, since it is wonderfully susceptible of fine carving. The quarries in *Pudukkottai* district not only supplied the materials required for the structural enterprises of the district but also to the adjoining *Thayyasar* and *Thiruvannamalai* and hence *Pudukkottai* is termed as the "Cradle of Granite" of the region⁵.

Historically, the *Pudukkottai* tract was the meeting ground of the boundaries of the famous Tamil kingdoms, the *Pallava*, *Chola*, and *Pandya* and later of the *Vijayanagar* empire. It has been consequently, a land of battles and battlements. But if it suffered from an excess of the 'rush of horses and waving of flags', it's

better location also led to the area benefiting from the cultural traditions of the early kingdoms. In it's small area (about 1700 square miles) Pudukkottai has a collection of the main representative styles of South Indian architecture. The *Palawa*, *Chola*, *Pandya* and *Vijaynagar* styles are all present here at an optimal level of excellence. Thus Pudukkottai presented an open ground to all these dynastic styles for experimentation, demonstration and competitive display. Pudukkottai district has the distinction in having the largest number of ancient monuments in Tamil Nadu and they attest to the mastery of local craftsmen.

The *Cholas* right from the beginning in the 10th Century, erected temples in this district. Artistically the best known *Chola* monument in the district is the *Manarkoil* at *Kodambalur*. In elegance, proportion and ornamentation it is a lovely execution. Historically perhaps the most notable is the *Vijayalayaeswarar* at *Northankalai*, which combines *Palawa* serenity with *Chola* form. The *Irakkai* and *Mathuraya* chiefs have achieved the art and technique of construction of these temples in hard stone in the early *Chola* period.

Kodambalur is a place of ancient renown. The *Manarkoil* is the centre of attraction here. The *Manarkoil* was built by the *Irakkai* chief *Bhoja Vikramachari*, a feudatory of *Sardara Chola* (C.956-973 A.D.). These structural temples are of great beauty and most outstanding monument of South India. Originally there were three shrines facing west in a row in north-south direction. But only the central and southern are now intact and the basement of the north alone remains. Each shrine is 21 feet square at the base, 32 feet height. They are built completely from basement to finial of well dressed gneiss blocks neatly and accurately fitted. The walls are five feet in thickness. The plinth of each of the three shrines rests on a lotus base. The walls are decorated with a series of tetragonal pilasters and niches in the middle. The *sanctuary* is of two tiers. The sculptures in the wall niches and the *sanctuary*

are finest creation of Tamilian art. Some of them are now housed at Government Museum, Pudukkottai and Chennai.

Vijayalayaeswarar is a striking structure in the Pudukottai district. It is located on the top ledge of a hill. The main shrine facing west is built from basement to finial of well dressed gneiss block, consisting of the *navara* and a square *arabamandapa*. The spire of the *navara* is unique in style. It has four storeys in circular form. The *shikara* is dome shaped (circube) and constitute a single storey of the type in Tamil Nadu. There are sculptures on the *navara* and parapet wall of the *arabamandapa*. This temple is datable to mid 9th Century A.D.⁶ and built by *Motharaja* Chief. No doubt that these monuments are the land marks in the art history of Tamil Nadu. The stone for the construction of those temples might have come from the quarries near the temple sites themselves. They are of granite gneiss variety. But they have suffered the wrath of weathering due to the action of various agencies, since they are exposed to open sky for a thousand years. The present status of the granite in these temples are discussed in this paper.

The stones for the construction of the temple are examined and selected carefully, as per the norms prescribed in *stupa sastra* texts, to withstand the test of time. A detailed study of the qualities of the specific stones, their marks etc., are described in various *stupa* texts⁷. Even before the stone is quarried, the suitability of the stone for temple building is ascertained by rigorous tests. The colour, sound, shape etc., are well studied. Stones with cleavage, rays, black spots and from saltish water area are discarded. Selected stone is severed from the rock and taken to the building site, seasoned suitably for building and carving. The Hindu temple is the sum total of *sams* performed on the basis of it's myth. Since stone is quarried by force they have been rent from their living context, so, the *sapathy* and astrologer go to the quarry and propitiate the spirits, gods and *gaur* who live in the stone, with the request to change their abode and depart quickly. Then

only the stone is removed to the temple site workyard and is kept for about six months, seasoned (as wood) by putting in water and taken out, dried and carved. So the stones for temple building were very carefully selected.

The modern scientific method also envisages to test the durability of the stone for architectural purposes. First, it is examined in its natural ledge and then quarried. The stone is put in water and if it does not gain water it is considered as a good one⁸. It will be seen that the knowledge is a continuing process.

In spite of such best selection by the *stapati*, the granite in these monuments of our study show decaying trend. The stones are flaking in layers in many parts of these temples. Some of the sculptures have lost their carving on the front face and lost their identity. The Archaeological Survey of India has taken best efforts to protect their structural beauty. But the decay in granite has occurred over the years and this may be due to the action of various agencies such as mechanical, chemical and natural.

Sources of Weakness

An average granite affords silica 72.07%, alumina 14.81%, iron oxides 2.52%, lime 1.63%, magnesium 0.33%, potash 5.11%, soda 2.79%, water 1.09% (=100.35). The gneiss is also similar in constituents and colours but the ingredients are arranged more or less in layers, easily paving way for slaking⁹.

The durability of the granite depends mainly on its degree of porosity and the presence of minerals of easy destruction. The porosity may be general in the rocks or different along different planes and laminar and it increases due to rifts and cracks. Porosity may allow water and air to gain access together, with in the rock, disintegration and decomposition will be going on wherever the rock. Further presence of some weak minerals makes the granite less durable. For example, when minerals such as alkali or lime is present in the granite, it looses its potash through the infiltrating waters, changes to clay or kaolin, starts

crumbling. The iron contents oxidise destroying the black mica and the stone is reduced to sand or rusty earth. Iron combined with sulphur oxides in to sulphuric acid causing discolouration and decay. Such chemical changes push the grains of the stone apart and creates or extend rifts. So porosity, rifts and cracks speed up the destruction of the granite by the above chemical actions. These are some common evils in carelessly selected building stones.¹⁰

Alternate heating and cooling from changes in temperature between exposures to sunshine and shadow, day and night, warm season and cold, sun's heat on rocks during the day and cold waters and so on, causing expansion and contraction and hence superficial disintegration of granite after granules take place. The unequal expansion caused by a given amount of heat in different minerals present in the granite is supposed to enhance the disintegration effect. The growth of microscopic life in rifts and pores widen them. In granite the less mica the more durable the rock, because mica tends to increase porosity. When polished usually granite resist all weathering agencies, because polished surface has no depression to catch and hold of water but dries almost immediately after wetting.¹¹

Status of Granite

Thus being the general nature of the story of disintegration of granite, now let us focus on the status of the granite in our monuments under study.

The *Manukotai* at *Kadambakur* is well preserved structurally. But the granite is flaking in layers like plates in many places. The same is the case in some sculptures where the layers in the granite have fallen in patches. For example the *Arāhanasvara* in the eastern wall of the central shrine, *Gangadara* in the east, and *Vināyaka Dakṣinamurti* on the south, in the southern shrine are a few to cite. These beautiful sculptures are loosing their fine carving due to flaking. The flaking may be due to the action of



Marudhai at Kadambalur

northern wall niches of both the shrines have nearly disintegrated beyond identification, as if they are made of clay or kaolin. How these two sculptures alone worst affected so much? Incidentally there is a sculpture of *Siva* from *Kadambalur* (*Bekalidanamurti*) at Government Museum, Pudukkottai, in similar condition. I am of the opinion that this sculpture may belong to the north niche of the northern shrine, now completely lost. It is curious to observe that the sculptures in the northern wall of the three shrines have suffered disintegration alike. Will it be due to the excessive force and action of monsoon, wind and water? It is difficult to think that the stone for these sculptures alone might have brought from different site. But it is due to same action.

Some of the sculptures excavated in a site adjacent to *Marudhai*, are now exhibited at the Government Museum, Chennai¹² and the granite is in good state of preservation and has no sign of decay. Is it due to the fact that they were buried under the earth for a long time? Some of the loose sculptures from *Kadambalur* that are housed at Government Museum, Pudukkottai, also show some point of

water on the weak chemicals there is as described *agru* and weakening the bond of successive layers. Detailed study is necessary to prevent further flaking and peeling of the granite layers. It is surprising to see that the sculptures of *Siva* on



Marudhai Kadambalur Siva in the North Devakuladevi in the Northern Shrine

decay like flaking. Any how, the *Kodambalur Maavarthini* is an interesting site to conservation practitioners. It is for them to suggest appropriate chemical treatment according to the nature of the granite and defects there in. It may not be out of place here to mention that a recent research has shown that ethyl silicate with acrylic resin will be a good preservative to bind and consolidate such flaking and granular disintegration of stone sculptures¹³.

Narthanasalai is a small village and has nine hillocks in it's fold and supply fine variety of granite for architectural purpose even this day. The *Vijayaalambalinarum* here is located on the eastern ledge of a hill. Hence the action of wind may be minimum, but weathering has not spared this temple also. The sculptures on the parapet wall of the *ardhamandapa* and *Vishaya* have lost their fine carving due to weathering and action of disintegrating agencies and continuous exposure to heat and cold. Among the *Dvarapalakas* in the entrance of the *ardhamandapa*, the one on the northern side shows more signs of disintegration. This is again an interesting point with reference to the cardinal direction and preservation status of building materials and sculptures. The stones in some parts of the temple are flaking in patches. The structural beauty of this temple is well preserved but the granite shows disintegrating trend. But it can be said that the effect of disintegration is lesser than *Kodambalur* monument.

Though the disintegration noted in these monuments, which are aged a thousand years is more due to the natural, chemical, mechanical agencies. However detailed investigation and tests by conservation etc., may be helpful to minimise the harmful effects of these glorious monuments with original artistic beauty.

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Problems Related to Transportation and Display of Stone Sculptures in the District Museums in Tamilnadu

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The Department of Museums, Government of Tamilnadu has 20 district museums, most of them located in the district headquarters. The district museums are of multidisciplinary type with a fairly good collection of stone sculptures. Even though the collection is good, the district museum Curator encounters with many problems during the process of acquiring, transporting and the display of stone sculptures. Some of the problems are dealt with in this paper.

Problems During Acquisition

In the district museums, the stone sculptures are mainly acquired as stray finds. The Indian Treasure-trove Act, 1878 defines that anything underlying the earth or anything, which is unclaimed belongs to the State. If it is more than 100 years old, it is declared as an antiquity. Whenever a sculpture is declared as a treasure-trove, the District Collector allows it to the concerned district museum. Even though these procedures are over, when the Curator goes to collect it at the locality, he sometimes faces problems. For instance, the villagers refuse to part with the sculpture claiming that the sculpture is under worship.

Problems Related to Loading of Sculptures

Sculptures are acquired from the respective district or from the nearby districts. In some cases, the sculptures are found in

different elevations. Vehicles cannot go to the spot where they are found. Therefore, creating a accessible path up to the vicinity is necessitated. More labourers and materials are involved in this process, which is practically unaffordable for a district museum. Arranging sophisticated elevators is also a costly process, since most of the district museums face financial crunch. The most commonly used implements for lifting the sculptures are simple tools like iron rods, crowbars. Wooden planks are used as inclined plane and ropes are used for lifting them up. During the process of lifting, sheer negligence of the labourers, causes damages like breakage of sharp protrusions of the valuable sculptures and some times even severe damage. Proper padding of the sculptures is very much essential during lifting and loading.

Problems Related to Transportation of Stone Sculptures

The rural roads are not proper and hence the difficulty in transportation. Damaged and improper roads cause damages to the loaded sculptures, if they are not properly padded. Overloading of sculptures in a vehicle also causes damages. Some district museums are organised in the upper floors of buildings. Lifting heavy sculptures to the galleries is also a tedious process. The Curators have to plan accordingly for the safety of the sculptures. A participatory approach of the museum personnel, engineers and labourers is needed for the safe transport of sculptures.

Problems Related to Display of Stone Sculptures

Most of the district museums in Tamilnadu are housed in rented buildings. Some buildings are small. It is very difficult to display all the stone sculptures inside the galleries. Therefore, the sculptures kept outside the building get deteriorated due to physical, chemical and biological factors. Some district museums are located in the vicinity of seashore. Salt encrustation is noticed in these areas. Most of the stone sculptures are displayed by embedding into the masonry pedestals. In order to avoid entry of salt laden water, a barrier should be provided in between the

sculpture and the masonry platform. It also helps the sculptures from cracks due to earthquakes. The visitors to the museum always touch the sculptures. The graffin marks made by the mischievous visitors and prolonged touch made by them reduce the aesthetic value of the sculptures. Prolonged exposure to sunlight and rain also cause deterioration to sculptures kept outside the museum building. Salt encrustation and leaching will lead to the weathering of stone sculptures. Pollutants affect them. The major pollutants are oxides of carbon, sulphur and nitrogen. Biological agencies like algae, fungi, moss and lichens cause deterioration to the sculptures kept outside the museum building.

Conclusions

It is evident from the facts that proper display and conservation measures must be taken to avert the problems mentioned above. Curators must be aware of the basic conservation techniques so that they can easily solve these problems. Nowadays, the district museum Curators are given in-service training in chemical conservation. Awareness is essential in the preservation of stone sculptures because they reflect the history and culture of the past society. We can increase the life expectancy of the stone sculptures by providing a friendly environment.

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Stone Objects and Their Environment

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Industries and transport system are very essential in the modern world. Factories exhaust many gases. Especially motor vehicles (automobiles) emit oxides of carbon and sulphur. Now the Taj Mahal, the marble miracle, is severely affected by fumes of refineries. The stone sculptures of the monuments at Mahabalipuram are very much affected by salinity. We can classify the environmental factors into two categories: viz. (i) Natural factors and (ii) man-made factors. This paper discusses about the friendly environment to the stone sculptures.

Natural Factors

Sea breeze along with fine sand blowing from the sea-shore severely attacks the stone sculptures.

If it is a museum in a sea shore, it is better to shift the museum from near the sea to a distant place. If it is a monument, chemical conservation is the only solution. Sand blast from the shore may be arrested by building huge walls and vegetation around it for unremovable sculptures.

Sun-rays and Rain

Sun-rays and rain affect stone sculptures. Sun-rays produce heat on the stone sculptures. Showers spoil the upper layer of stone sculptures.

Such stone sculptures should be exhibited and displayed safely and protected from showers and sun-rays.

Earthquake

Recent earthquake in Gujarat has raised the question for protection of stone sculptures. Earthquakes and tremors give sudden jolt to the stone sculptures. Stone sculptures should not be placed directly on the cement platform or embedded on the wall. A plastic buffer element provided in between the sculpture and cement platform will protect the sculpture from cracks during earthquakes. Wooden pedestals are best for stone sculptures, which avoid direct contact on the floor. These are the natural factors, which affect stone sculptures. Providing friendly environment to the stone sculptures can curtail the factors, which are caused by nature.

Industries

Industrial revolution is a milestone in modern life. Because it improves the national income, offers placements for unemployed and raises the standard of living, but at the same time industrial emissions such as sulphur-di-oxide, nitrogen oxide, hydrogen sulphide and other corrosive gases not only cause diseases to human beings but also affect stone sculptures and stone structures.

Shifting of such industry or museum is the only way for preventing stone sculptures and structures from man-made pollution. In the case of the Taj Mahal, ban on such industries is essential.

Transportation

Transport and polluting vehicles are the other man-made problems to the museums, which are located on the roadside. Noise pollution and chemical pollution by motor vehicles very much affect the environment of the museums, which are near the roadside or on the highway.

Vibrations made during movement of heavily loaded motor vehicles traffic will cause development of cracks in the stone

sculptures. To provide a friendly environment to the stone sculptures is to divert heavily loaded transport vehicles from the road adjoining the museum building and the blowing of horns may also be banned for protecting weak stone sculptures from noise hazards, making no-entry zones near museum is equally essential.

Shifting Stone Sculptures to a Newly Constructed Building

Recent experiments proved that newly constructed concrete structures will expel very minute particles. These finest particles will affect stone objects. Using such new buildings after completion of two years from the date of construction or after passing two summer seasons the building will provide a friendly environment to the stone sculptures.

Fire

Outbreak of fire can be natural or due to human error also. Switching off the electricity all the galleries after visiting hours will prevent fire accidents in locked galleries. Refilling the extinguishers in time will help to control fire.

Conclusions

Stones are inorganic materials, more stable than metal icons. Even though they are stable, polluted environment spoils the sculptures. In our country museums are mostly associated with stone sculptures. The stone sculptures reveal their age, culture and historical value of the past society. We can extend their life span by providing a friendly environment.

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Overview of the Legislative Framework for the Protection of Our Cultural Property and Suggestions for Improving Implementation

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Every country is justly proud of its cultural heritage. India is especially blessed in this regard due to its having been the cradle of civilisation for the past 10,000 years. This has given rise to several heritage structures due to the building activity of successive monarchs. Therefore, conserving and restoring heritage monuments and sites to their original state has become important. There is a legislative framework for protection of monuments whose custody has been taken over by the Union or State Governments. The high value that the antiques command especially in the illegal art market is due to the poor prospects of their being replicated. The masters who produced them have died long ago. Laws have been framed to regulate traffick on in such antiques. It is illegal to trade in them or export them without permission. Therefore, there is need to protect them so that they do not end up in the illegal art market.

Role of Museums in Generating Public Awareness

Government Museum, Chennai plays its due role in making the public aware of the need to conserve and protect our rich cultural heritage. The subject was dealt with exhaustively in a seminar on "Our Role in Protecting Cultural Heritage" held in this museum on 22-5-2001. A souvenir has also been brought out in which

the papers contributed by the leading experts who participated and the consensus that was arrived at are presented. The views expressed have been duly conveyed to government. I am sure museums and archaeologists elsewhere must be acting as similar Think-Tanks.

In this paper along with the legal framework, we look at the practical problems in enforcement. New suggestions for dealing with antiquities and heritage structures have also been made.

Legal Framework in India

The pioneer attempt in this direction was by Lord Curzon, who got the Ancient Monuments Preservation Act, 1904 passed. This Act provides for protection of and preserving of ancient monuments, which were considered important and of objects of archaeological, historical and aesthetic interest. Control on traffic in antiquities and over the excavation in certain places was also provided for. This act was not effective. The penalty provided was a fine of Rs.500/-, which was not adequate. It is not proposed to trace the entire history of legislation and evolution of thought, since that is not the objective of this paper. Only the current laws and the past laws that have a bearing on current laws are dealt with.

Protection of Monuments and Other Heritage Structures

There were other legislative measures for the protection of historical monuments in course of time. As of now the legislative framework is supplied by the Ancient Monuments and Archaeological Sites and Remains Act, 1958 administered by the Archaeological Survey of India (ASI). The ASI notifies important monuments, excavation sites and temples as protected under this Act. Once notified, it appoints watchmen to safeguard the heritage monument or site. Other agencies or private persons cannot undertake any repair or exercise any manner of control over the monument except with the permission of the ASI. There is a counterpart Act in Tamilnadu under which the State

Department of Archaeology functions. This is the Tamil Nadu Ancient and Historical Monuments and Archaeological Sites and Remains Act, 1966 (Tamil Nadu Act 25/1966). Under Section 3(3), the final notification is made after making a preliminary notification under Section 3(1) inviting objections. This is done in the Port St. George Gazette by the Government of Tamil Nadu. The powers are roughly the same as given to the ASI. The State government takes control of monuments, which are not considered of sufficient national or international importance for the ASI to take control and maintain them. In respect of new excavations, permission has to be sought from the ASI under the Ancient Monuments and Archaeological Sites and Remains Act, 1958. Thus, all aspects of heritage monuments are brought under the control and regulation of the Union or State governments.

Laws Dealing with Antiquities

In a country with a long history like India, layer upon layer of civilisation is found. Antiquities in large numbers are found buried in the earth. The Indian Treasure-trove Act, 1878, was passed to acquire the treasure or antiquity found buried for the government. Under this Act, it is obligatory for the finder whenever he comes across any unearthed antiquity, whose value exceeds Rs.10/= (Rupees ten only) to report the matter to the government. The State Governments were empowered to frame rules under the Act. The government of Madras (now Tamil Nadu) has framed a set of rules known as Board Standing Order 197, Appendix II, para 8, under which the treasure-trove objects are being dealt with and disposed. All land belonged to Government was a theory invented in the *Ryotwari* System in Baramahal district by Col. MacKenzie and Reid to get over the confusion regarding the land tenure systems. They said only the surface rights belong to the property owner. This is a relic of feudalism. Therefore, the finder or owner was not entitled to anything found under the surface of the soil.

When the treasure is acquired by the government, the finder and the owner of the land from where the treasure has been unearthed are paid compensation by the government. The finder gets 75% and the owner of the place gets 25% of the metal value of the objects, plus one-fifth of its value. The Act has been helpful to large extent to acquire objects of antiquarian and priceless art treasures, but it is not free from defects. There is no method to ensure that such discoveries are reported. The penalty for not reporting to the government under the provisions of the Act is the confiscation of the share of the finder and one year's imprisonment or fine or both. There was no provision under this Act to check the illegal export of antiquities.

Under this Act, the antiquities, which have been in existence for not less than one hundred years, are to be registered. Stone sculptures, terracotta, metals, ivory and bone, paintings, manuscripts and wooden sculptures are also covered.

Regulation of Trade in Antiquities

James Burgess, the then Director General of Archaeology wanted to stop the activities of art dealers and collectors. But it was only in 1947, Parliament passed the Antiquities (Export) Control Act, which was repealed and the Antiquities and Art Treasures Act, 1972 was passed. An antiquity is defined as object more than 100 years old. It regulates the export trade in antiquities and art treasures. All exports have to be authorised by the Government of India. The ASI is the authorised agency to give such clearance in practice. A committee regularly meets in Fort St. George at the ASI office under the Superintending Archaeologist to give such clearances. But it does not allow the export of antiquities. Internal trade in antiquities is regulated by licensing etc. Registration of antiquities in the possession of private persons and institutions is compulsory. Government of India can compulsorily acquire antiquities and art treasures held with private

persons. Stringent penalties for offences in contravention of the provisions of the Act have been provided.

The works, paintings, sketches, diagrams and the like and the objects of plastic art of the following artists are declared as art-treasures for the purposes of this Act. The authors of these works of art are not alive.

Rabindranath Tagore, Amrita Sher-Gil, Jamuni Roy, Nandalal Bose, Raja Ravi Varma, Gopendranath Tagore, Abanindranath Tagore, Sankar Mukherjee, N. Roerich

The works of artists like Raja Ravi Varma have been recently declared as national treasures.

Current Position of Art Theft

The figures of art theft and illegal export started rising when art became a method of storing huge illegal wealth. This explains the rising trend of art theft. The important effect of the Act of 1972 is that it would help in tracing the missing antiquities within India and help to claim them back from any foreign country in the event of smuggling on the basis of documentary evidence, since it would be now registered as a result of the Act. But there are other tendencies like the smuggling of antiquities along with recently manufactured artefacts as art treasures, handing back of treasure trove objects to villagers, which increases the prospect of illegal traffic.

Intellectual Property Rights

Intellectual property rights, which are intangible, are as important or even more important than physical property since they earn repeat revenue for commercial interests. It is possible to misappropriate the symbols of one culture like the *Nataraj* figure by commercial interests for their commercial exploitation.

The right to copy information, the right to copy designs and inventions was also controlled leading to the Patents & Designs Act, 1970, Trade and Merchandise Marks Act, 1958 etc. The laws

ensured that no person who had registered his design, copyright or trademark would be deprived of it except by law. In other words, it became a form of intangible property. The Copyright Act, 1957 protects authors from copying of their published works till 50 years after their death. In the case of government publications it is 50 years from date of first publication or republication. In the case of patents, it is usually for 30 years. This ensures that knowledge becomes free after a certain length of time.

Recent Changes in Laws

Patents were usually for products under the old regime before the World Trade Organisation system was introduced. Therefore, products with variations on the originals could be produced without infringing patent laws. Now after World Trade Organisation (WTO) and TRIPS (Trade in Intellectual Property Rights), Process patenting has also been introduced. This adversely affects developed Third World Countries like India because free use of technology even with variations is not permitted. After many debates, Parliament has passed the new laws in 1999. The new Act will conform to WTO protocol.

Steps suggested to protect and conserve heritage monuments and prevent illegal traffic in antiquities and art objects

Protection of Heritage Structures and Monuments

It has become a practice to indiscriminately declare all ancient structures as heritage monuments. It is treated as an anti-poverty programme. Such an approach by spreading resources thin will only ensure even deterioration of these protected monuments. Only a few important monuments must be declared as protected, but by concentrating resources they should be conserved so well that they become models and attract heavy tourist traffic, thereby generating revenue. This makes them self-sustaining.

In other cases, those who demand that a monument be declared protected may be licensed to protect and maintain it according to heritage principles. The ownership will however, vest with the government. They may be even licensed to collect entry fee at an agreed rate by government. State intervention has to be minimal and regulatory in nature rather than be the 'Great Provider or Doer'.

Creation of Legal Antiquities Market

In a situation where there is no legal place to buy and sell antiquities, sellers and buyers are forced to deal furtively. This gives rise to illegal sale and purchase. When a person who owns an antiquity wants to sell due to his need for money etc., he must have a place like Sotheby's or Christie in London where he can sell. There must be a licensing and regulatory mechanism to regulate such trade. The antiquies must be certified as legally saleable, for example sale within India. Then trade, which is at present underground, will become regulated. It will also fetch huge revenue to the government as sale tax, income tax, capital gains tax etc. It is easier to regulate a given area than police a widespread area.

Reward to Finders and Owners of Treasure - *troves*

Some people argue that in several countries it is legally mandatory to part with treasure troves to the government. Therefore, they argue for strict enforcement with deterrent punishment rather than rewards to the finder/owner.

A more sensible view appears to be that a Carrot and Stick Policy alone will work. Some part must be kept with the State and some part must be parted. After all, what are we are parting with? We found a gold bowl somewhere found by a *swat*. We are giving the gold price not the antique value, which is kept by the State for itself. If you take a *panchabada* idol, the antique value is worth crores of rupees, whereas the metal value will be a few hundred or thousand rupees. In fact, this is itself acting as an inducement

to a person to conceal what he has found. Nobody can really police every square feet of this vast country. It is ideal to expect that everybody will be a *Haribanshu* (Indian monarch famed for telling the truth). In the modern market economy, stick alone will not work. More Carrot than Stick is required. Therefore, I believe that the government should do a little more to induce people to report finds by at least parting with a part of the antique value. The honest ones should be given some recognition - some certificate.

There is a tendency in recent years for certain vested interests in villages to induce a law and order problem to prevent the idols and bronzes recovered as Treasures being taken out of the village and deposited in museums. District Collectors are also not enforcing the provisions of the Treasure-trove Act in such cases. The plea made is that they are needed for worship. According to *Agama Sanitru* (rules regulating worship in temples) such idols, which are usually defective in some respect should not be worshipped. In fact, such idols are supposed like a dead person in the ground. Therefore, the demand for keeping them for worship is a cover for illegal activities. Substitution of antiques by fakes as in the *Singuram Natraya* case happened only due to such a practice.

Check at Exit Points of the Country

There are several exit points in our country. Cent percent check of baggage/cargo has become impracticable. But, random check has to be done. Recently, in a diplomatic baggage a huge quantity of idols was recovered.

Usually, the Customs Department and Idol Theft Wing of the State Police have brought to our notice that while stuffing containers along with recent copies of idols or other artefacts, some antiques are mixed and sold. The latest trend to give an antique look to bronzes makes matters more difficult for the

enforcement authorities. They have to seek expert opinion of the Museum or Archaeological Department personnel.

Finger Printing

Finger printing of all important images (i.e.) early, typical and rare bronzes has to be taken up. Finger printing of the pedestal has to be done to correlate it with the main image when discovered. This may be slowly extended to other varieties. The results of these findings are to be stored in the Government Museum, Chennai and the Idol Theft Wing of the Tamil Nadu Police. This will enable ready access.

Registration by Electronic Means

A paradigm shift in documentation from paper to paperless digital form has occurred by the use of the computer. Steps have been taken in the Government Museum, Chennai to electronically document the collection. The collection starting with the important objects classified as 'AA' and 'A' are to be put out in CD-ROMs.

Documentation of objects in villages, similarly, has also to be done. Each Taluk Office has now got a computer. They can easily therefore register such objects in the village. The antiquities in the villages should be put on CD-ROMs. These should be available for sale. This will generate revenue besides ensuring transparency. If knowledge is widespread, then misdeeds cannot be done easily. It would have been easier to deduce that the *Singaperum Nataraja* was replaced by a fake, had the knowledge about it been widespread. Substituting by a fake can be detected, not necessarily by a government official, but also by a foreign tourist or an Indian tourist. They can inform the police or the media so that such theft is detected.

There should also be a system of annual inspection of the places, where idols and antiquities are stored. There must be a test check so that any officer who goes on tour from the archaeology

department, from the museums or even the revenue department or police will check up whether the antiques are there. If they are substituted with fakes or totally misplaced but there will be some one to blow the whistle.

I stressed on the need for registration under Copyright Laws to prevent such misappropriation. Photographs by digital methods and documents on computer can be made into CD-ROMs so that everybody knows what is in the collection in Chennai museum and other museums of the Department of Museums, all the two hundred thousand to two hundred and fifty thousand artefacts that we have. If the current old manual Accession Registers are lost, no one will know what has been lost.

This topic is also exercising the Government of India judged by their insistence on documenting the important artefacts in digital form.

Insuring of artefacts is a new concept. The principle of indemnification is modified to the agreed value indemnification in the case of rare art antiquities. This was stated in a presentation in the seminar on "Our Role in Protecting Cultural Heritage". This presentation gave a new insight into insurance since the concept of insurance has yet to catch on in the field of museology. I do not know whether we can afford to pay this kind of premium for example Government Museum, Chennai has two hundred thousand artefacts. Can we afford to pay or can any government afford this kind of payment?

Problems Due to the New Laws on Intellectual Property Rights

We have to be very careful that a rampant situation that arose like the patenting of Neem or Turmeric or Basmati in USA does not occur.

Museums, art galleries, manuscript library authorities etc., must get all the art and ancient objects and manuscripts in their

collection registered with Copyright/Patents/Trade Mark authorities to ensure that their intellectual property rights are not stolen by others. They may even force the original owners to pay for their use. E.g. A *Natarajis* statue can be photographed and registered as a trademark or design in U.S.A. Then the museum where the icon is originally on display will have to pay to the new American owner. This calls for a common approach either for mass registration or registration only with the consent of the original owner. Another point is that the museum or library may not have sufficient funds to fight the case in U.S.A., some method of *en masse* registration of all such collections by Indian authorities has to be thought of to prevent such a potentially hazardous situation from developing.

In the case of manuscripts dealing with medicines etc., the situation calls for attention even more. Here millions of dollars are involved. Our own Indigenous Technical Knowledge (ITK) can lead to drug formulations, which are sold back to us at a high price.

Similarly in the case of paintings, it is conceivable that a design based on a *Raja Ravi Varma* painting can be registered abroad and commercially exploited. The situation will lead to the original museum or owner not being able to exploit it or display it in its brochures.

Our *agar* or dance forms like *Bharatanatyam* can also be patented by persons who change the name and claim it as their own.

Remedies

In order to avoid this potentially dangerous situation, we may need to do the following.

1. Create awareness among all the staff and people who deal with our heritage and even the general public on Intellectual Property Rights.

2. The collections in our public and private museums, which are already entered in the Accessions Registers, registered - either by an *overall* class or by specific registration.
3. Make it legally impossible to register designs or Indian objects abroad without notice being first issued to the concerned Indian owner of the original object/manuscript.

Participatory Approach

A Participative Approach in the Participatory Rural Appraisal (PRA) mode of learning from and with the stakeholders like owners of manuscripts, paintings, practitioners of indigenous medicine, museologists, archaeologists will enable us to learn more and implement the suggestions for safeguarding our tangible antiquities and intangible cultural property rights. In the field of conservation of heritage monuments, a committee of the agencies involved in this field like the Archaeological Survey of India, academic experts from Indian Institute of Technology, the State Departments of Archaeology and Museums, serving and retired personnel of these departments who have acquired specialised expertise over the years must be associated in the conservation of these monuments on proper latest principles of conservation. However, care must be taken not to include those who masquerade as experts without real knowledge.

Steps Taken by Government of India

It has been seen above that the Government of India is insisting on registration of the valuable artefacts in museums classified as 'AA' and 'A' in electronic form with their photographs. Dr. Vaidyanatha Ayyar, the then Secretary, Department of Culture had meetings with the Secretaries in charge of Culture of the States and Directors/ Commissioners of Museums on this subject. A CD-ROM containing the programme called 'Natyaj' and a template for recording data and photos of important objects has been sent to leading museums. The work of documentation in respect of this museum is complete.

Conclusions

We have seen in this paper the need to protect the ancient monuments and heritage structures that our old culture has given rise to. The legislative framework, which operates in India and Tamilnadu, has been gone into. It is seen that the legal framework has evolved as a result of the rising levels of awareness on the need to protect and preserve our past heritage. Current market forces like illegal art sale have also played a part. The need for an institutional framework for the antique market has been stressed. The need to evolve new laws to regulate and encourage pooling of expertise and private initiatives in conservation of heritage structures is another new area covered. The need to enforce compulsory registration of antiquities, their electronic documentation for easy retrieval has been stressed. Finger printing of bronzes is a hi-tech initiative taken by this museum in this regard. Intellectual Property Rights on antiques and heritage structures is another greenfield area, which has been analysed and measures for protection of rights suggested. Along with rigid law enforcement, a more market oriented practical approach has been suggested to ensure recovery of treasure-trove objects. The need for a regulated market is in tune with this market oriented approach. It is hoped that this new approach will not horrify the traditionalists in this field, but they will approach these new ideas with an open mind. The present economic scenario dictates this new approach if protection of our culture has to be done effectively. No amount of laws without enforcement and people's support will succeed.

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International Law for Protecting Objects of Art from Illegal Trafficking and Theft

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International Law provides measures protecting art and cultural objects from theft and illegal trafficking. The reasons are many. This paper discusses various conventions agreed at the international level among member countries. Agreed convention are being implemented by member States and they are solved. In this paper special reference is made to the Indian laws and the need to introduce penal provision such as rigorous imprisonment for theft and illegal trafficking cases and the same should be deterrent. Without knowing the root cause for this problem, it is very difficult to safe-guard monuments and heritages even at international sphere.

Reasons for Theft and Illegal Trafficking

In the case of illegal trafficking, the loss suffered by an institution or a nation may prove to be a gain to the end receiver organisation or country, but it is a total destruction. Due to advancement of science and technology, the modes operands are also changing in a sophisticated manner apart from the traditional methods.

The reason for increase in this sphere especially in the developed countries, where there are vast opportunities for international marketing, it is deemed to be a highly profitable and and lucrative one. If theft and illegal trafficking are not checked and stopped,

in the long run, a country's heritage, culture and civilisation will also be gradually ruined.

International Law and Conventions

In order to protect the world heritage, the UNESCO extends help by way of conventions and recommendations to the member States. UNESCO's first convention was Convention of Cultural Property in the Event of Armed Conflict - 1953.

The Recommendations of International Principles

Applicable to Archaeological Excavation 1956, starting from 1953, the last convention is the UNESCO's 17th Session held at Paris from 7th October to 28th November 1978, recommended the protection of valuable movable cultural property. This is one of the most important aspects. Apart from this, the International Council of Museums (ICOM) and the International Council of Monuments and Sites (ICOMOS) provide certain relevant and useful guidelines.

The General Conference of the UNESCO, at its Ninth Session held in the year 1956 at New Delhi, adopted the recommendations on International Principles Applicable to Archaeological Excavations.

The most important recommendation of the New Delhi conference states that in the higher interest of the common archaeological heritage, each member State should consider the adoption of regulations to govern the trade in antiquities so as to ensure that this trade does not encourage smuggling of archaeological materials or affect adversely the protection of sites and the collection of materials for public exhibition.

Foreign museums, in order to fulfill their scientific and educational aims should be able to acquire objects, which have been released from any restriction due to the laws in force in the country of origin.

In the year 1970, at Paris, in its sixteenth Session, another convention laid emphasis on the means of prohibiting and preventing illicit import, export and transfer of ownership of cultural property and this was adopted by the General Conference.

Pakistan's Antiquities Act of 1968 considers counterfeiting any antiquity by itself as an offence. Iraq's Antiquities Law prohibits forgery and the preparation of casts or moulds requires government's permission.

The oldest law in this field for protecting any cultural property has been enacted by France in the year 1809 by enforcing controls on the transfer of fine or rare properties from the State Archives.

The ICOM, in the year 1974, compiled a handbook on National Legislation, for elucidation and appreciation of the offenses that may emanate from any clandestine transaction.

Almost in all the countries export regulations are made rigid and very restrictive. In countries like Algeria, Austria the legislations for export of rare type of art or cultural articles or properties are stringent. Yet, some countries adopting liberal policy, do not follow a serious set of rules and regulations for obvious reasons.

In most of the countries, having rich cultural heritage, the export of such properties is prohibited, except without a valid permit or license.

A study of laws etc., in the European countries, reveals that liberal export policy is likely to begin with the U.K. Here a license is needed for the export of cultural materials and works of art manufactured or produced at least one hundred years before. In the U.K., a reviewing committee specially scrutinises objects of national importance and it may refuse license and re-acquire those objects for any national collection.

Laws in India

The first Act in this area enacted in the year 1878 was "The Indian Treasure - trove Act, 1878". The preamble of the Act states that the law relating to art objects being smuggled every where is bad and ineffective and gives every inducement to offenders to conceal or make way with their discoveries and yet there is a good deed of treasure buried in India and much of these are very antiquarian and of historical interest.

The salient feature of this Act is that the finder is to give notice to the District Collector of the discovery of the treasure and either deposit the treasure with the Government Treasury or give security for keeping it. The next one is the Ancient Monuments Preservation Act, 1904. This Act was enacted to provide for the preservation of ancient monuments and objects of archaeological, historical or artistic interest. This Act empowers the Central Government to issue notification specifying boundaries of the area protected. Section 20 provides that government can acquire the protected area. The penal provision of imprisonment for those who violate is 3 months and or fine upto Ra 5000/- or with both.

The Ancient Monuments and Archaeological Sites and Remains Act, 1958

This enactment provides for the preservation of ancient and historical monuments and archaeological sites and remains of national importance for regulating of archaeological excavations and protection of sculptures, carvings and other like objects, which had been in existence for not less than 100 years. Section 33 of this Act provides imprisonment, which may extend upto 3 months or with fine of Ra.5000/- or with both in case of violation.

The Ancient Monuments Preservation Act, 1904

The preamble of the Act provides for the preservation of ancient monuments and of objects of archaeological, historical or artistic

interest. Section 17 deals with "Trafficking in Antiquities" and the power provided to Central Government to control trafficking in antiquities.

The Antiquities and Art Treasures Act, 1972

The Central Government may give notification in the official gazette prohibiting or restricting the sale or removal of antiquities to the detriment of India or any neighbouring country. Any person who brings or takes, attempts to bring or make any antiquities notified in the gazette into or out of the territories in contravention of the said notification, shall be punishable with fine, which may extend to Rs.500/-. For offences referred to in sub Section 12 of the Act, the offender shall be liable to confiscation. An officer of Customs or an officer of Police may search any vessel, cart or open any baggage or package. Under Section 19 of the Act, the Central Government is empowered to compulsorily acquire antiquities and art treasures.

Penal Provision of the Act

Imprisonment for a term not less than 3 months, which may be extended to 3 years and with fine.

Important Cases

Om Prakash Narsing and another Vs. Delhi Administration

On 31st March, 1967 two sand stone pillars of great antiquity and beauty were stolen from Suraj Kund Temple in village Aman, District Karnal, Haryana. These antiquities belonged to 2nd Century B.C. and their value at that time was said to be around US \$500,000.

During the pendency of the case, Mr Naninder Nath Malik approached the Magistrate alleging that he is a research scholar and he needed the pillars for a detailed study and took custody of the pillars. Later on he handed over fake pillars to the court. This came to the knowledge only when the originals were traced and found in the London Warehouse of M/s. Spink & Co. Two

cases of conspiracies were registered against Mr. Narinder Nath Malik for the offence alleged in the first case U/s. 120 B read with Section 420 and Section 406 of IPC and the second case U/s. 120 B and Section 411 and Section 25 of the Antiquities and Art Treasures Act, 1972 and this was challenged. The Supreme Court of India held that the Magistrate had taken cognizance of the offence and the right of the police to investigate upon fresh information and two conspiracy cases were maintainable.

Conclusions

All the above enactments relating to ancient properties and monuments, historical and archaeological Acts followed in member countries require a thorough review for the purpose of introducing objective machinery to sternly deal with the offences relating to illegal trafficking and theft of art objects so as to enable the authorities vested with the required powers to investigate, prosecute and attach even the personal properties of the offenders, treating them as anti-social gangsters.

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Authenticating Stone Objects

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The importance of authenticity having been highlighted at the Nam conference on authenticity (1-6, Nov.1994) museum & cultural institution has become extra vigilant. Authenticity by definition means state of being true or of truthfully established origin and provenance. Therefore, authenticity of a work of art depends on the relation between the work itself and the place, the artist or period to which it is attributed. Authenticity can also be defined as of original creative source that sustains and proves itself. It could also be understood as a condition of the heritage resource, legally valid, reliable, original and genuine etc. Authenticity has to be maintained of the existing heritage resources from the past. They will form a reference for future memory and will, therefore, need to be conserved with due respect for the relevant issues. In order to keep their authentic creative capacity, we need the dynamic, well thought of conservation management and planning. This includes minute examination and documentation made before restoration / replacement, the quantity of replaced parts is minimised, the size, quality and the species of new material are the same as the previous ones, the workmanship is the same and the report is published after the work, the replacement / restoration would never violate authenticity. On the other hand, the provenance of a work of art depends on the place where it has been made and the source from which it has originated. It does not relate to time or period, since these may vary. For example, a Gupta sculpture may belong to the kingdom of Gupta, which is demarcated geographically but it may be early therefore, has to be specific to the various sources of production of Gupta

sculptures. The places thus may vary but within that demarcated areas of their kingdom. It could, therefore, be from that region, which could be specified accordingly.

Doubtful Authenticity

The persistence of traditional crafts, which are not converted into modern creation, is one of the basic reasons of doubtful authenticity. Lack of historical sense leads to belief that using the same material and technique as in the past is a correct way of saving the traditions. But, traditional crafts were the authentic expressions of a traditional society; they can no more be the authentic expressions of the present. This results into faking, which is unfortunately encouraged by mass tourism and demands for artefacts of the past. The permanence of the craft is in itself not enough to safeguard authenticity and hence the problem. Reconstruction are also very often due to the wrong views of some concerned people who intend their knowledge to be materialised on the object instead of past documentation in the form of drawings or models, which conserving the authentic remains without reconstruction, could lead to unfaithful revival. The real notional values of such artefacts stay within the authenticity of the tradition, which could be rediscovered, studied, safeguarded and not to be carried away by over enthusiasm.

Problem

There have been cases, where we have not been able to prove quickly that particular stone sculpture or sculptures belonging to India especially in the absence of proper documentation records, which could prove our legal ownership having claimed their return to India. It is needless to say, that a large number of our heritage in the form of sculptures have not been documented on scientific lines and hence the problem. Authentication of artefacts has to be on the basis of their documentation records prepared for their characterisation done on the basis of a detailed technical study, which we often term as fingerprinting. Such a study done

on a object immediately after its acquisition or discovery through excavation or having been part of a standing monument would be most significant in this endeavour so as to authenticate them initially or if and be at a later date. It is a huge task considering our vast cultural heritage and sooner we start it, better it would be.

Documentation

Very often most of the museums rely on stylistic documentation on the basis of personal judgment of Scholars / Curators since they neither have any facility for any in-house documentation nor do they feel its importance making the situation still grave. The textual, graphic and photographic (visible radiation and invisible radiation) documentation has to be completed in respect of each and every stone artefact in a collection. This has also to be supported by specific observation made on their chemical composition, photographic examination, radiography, macro photographic studies besides Scanning Electron Microscope (SEM) studies done to fingerprint the inner structure crystallographic details including the inclusion in-between various crystals, if any. This would leave no loopholes, which could be manipulated by fakers to mislead the scholars, museologists in general and conservation scientists in particular. Any surface deposits of soil etc., irrespective of stone sculptures recovered from excavation could also substantiate the claims of ownership on the basis of the soil composition by comparison of the residual deposits and the soil of the site from where it was recovered.

Scientific Study

Such a scientific study can deter their replacement, later repair in case such a stone object breaks accidentally while on display, in storage and / or during transit. It would also help in retrieving them back for the country in case of a theft or smuggling so that their legal ownership could be proved in a court of law.

Instances are there when it became very difficult to establish ownership for example Amin Pillars and their provenance etc., which travelled to U.K. and copies were transplanted in their place *in situ* besides a copy was seized by the Customs at Mumbai. It is needless to say that authentication studies have to be done on the stone objects *in situ*, at their new location and if possible on the stone at a nearby quarry near the monument / site from which a particular stone artefact has come. I am sure the fakers cannot match all their characteristics and are bound to make mistakes on which we may encash at the time of authentication. This would also monitor their health over the centuries / years and could help in adopting conservation techniques accordingly.

Plans for Fingerprinting

We must prepare petrographic / microphotographic slide collection of known images from a particular site for comparison and if need be, to authenticate these images or prepare a SEM examination records, which could be compared with slides of known objects. This could also help in the study of the inner, which a faker cannot match. Chemical composition could also lead to conclusion in this regard, if large number of comparison slides is prepared. Such a study could further be supplemented by taking microphotographs of various parts of stone image. Graphic documentation could also record the details on the surface, which would be too difficult to match but an expert eye can not be cheated while comparing the scientific details thus prepared. Exact nature of the stone used in making a particular image cannot be falsified under expert evaluation of the problem.

Stone from *Awarant*

As regards *Awarant* limestone sculptures are concerned these are spread in three major museums, as known to me, of the country, the Victoria & Albert Museum, London and some may be elsewhere also besides at the original site museum at *Awarant*.

It is necessary to include all of these locations in the comprehensive project to authenticate them as per plans stated above. The big question is how far we are serious about authenticating our collection especially of stone objects, are our institutions technically ready, financially sound and ethically ready for such a comprehensive project on the basis of their in-house infrastructure or possible collaboration with appropriate scientific institution in the country or abroad? Moreover, even if we have the technical know how, do we have the necessary urge for such a study on priority basis? Let us not be caught unaware and wait for such a study till any future mishap actually occurring, when perhaps, it could be too late.

Restoration Vs Authentication

There are a large number of stone sculptures of which either arms or legs or head are missing such as the armless torso of Mathura Buddha in the collection of National Museum, New Delhi, which look aesthetically perfect even in the present condition. Large scale reconstruction would go against their authenticity and the missing parts may be left as found originally otherwise there is no end of reconstruction, which would be misleading art historically and could give rise to falsification. It could also betray the style, period and provenance of the stone image. Reconstruction therefore leads to complication such as faking replacement and deception. It could also betray the historic sense, moral and ethical values of the profession. In short, such stone sculpture would never be the same again. Repair / restoration needed for providing physical strength to the object, if reversible, would stand on the grounds of scientific conservation if needed for safe display or storage. Repairs, which would not affect the authenticity, may be considered collectively by all concerned.

Conclusions

In the end, I would like to mention that it may be possible to authenticate stone images also on the basis of the scientific data thus prepared, which could easily be produced in a court of law in the country or abroad to prove legal ownership. Such a study would also be a useful addition to knowledge besides safeguarding this priceless heritage resource for all times to come. All institutions should help and collaborate in this project to make it a success.

Authentication and Dating of Antiquities

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Any scholar who deals with sculpture or any other art object must have the required knowledge in authenticating and dating of the object. One has to authoritatively define the identity, style, date and regional variation of the particular specimen. For such careful study, one should rely upon *agave* texts on iconography, literature, local legends, *patanas*, inscriptions etc. The scholar's personal experience also will be helpful in some rare cases.

Problem of Identification

Problem in identifying sculptures arises where they are in groups. For example, in the identification of each goddess of *Saptamatrkar*, one has to get clue either from the iconographical features like weapons in hands or *vehana* related to each sculpture. We face the same problem in the identification of *Rishaba Vahana*, *Rishaba Arada* and *Rishaba Asthika* sculptures. Some identify them in general as *Rishaba Vahana Deva*. If Lord *Siva* with *Parvathi* is simply standing before a bull, it is named as *Rishaba Vahana*. When they are riding on the bull, it is called as *Rishaba Arada*. But where the bull is absent but Lord *Siva* is shown so as his right elbow is placed on the bull, then it is identified as *Rishaba Asthika*. This minute difference could not be known to all who deal with sculptures.

In rare sculptures where controversy persists on the identification, literature, experience and the scholarship of the researcher lead to a solution. For example there is a sculpture at *Darumaram* with three faces and eight arms. Previously it was identified as

*Arbharasimura*¹. Dr. R. Nagarwamy convincingly identified it as *Vishnu Maya* or *Maha-Maya*² (Devi, the Sister of Vishnu and consort of Shiva). In the same manner, a rare tantic sculpture found at a temple of recent origin at *Danavaram* was identified by Dr. Nagarwamy as *Chokryi* and dated to 12th Century A.D.³

Identification of Chocka Ravuthar Sculpture

Still controversy prevails in the identification of a sculpture, found at the entrance of the Thousand Pillared *Mastapa* at Madurai Sundaravarra temple. It was identified as *Daimy Arjunaatha Madali* who served as great general and minister for the first three Nayak rulers and caused to construct the thousand-pillared *mastapa*. But, now it is identified as Lord *Sandaravarra* himself who came as a horse trader in disguise to protect his devotee *Manikka Varaha*. Locally now it is called as *Chocka Ramethar*⁴ (a Muslim horse trader). This identification is arrived by the scholar with the help of a jackal figure found on the base of the sculpture, which leads ones memory to *Thiruvilayadal Perumal*. Although the conversion of jackal into horse is mentioned in the *Appar Desavam*⁵ itself (7th Century A.D.), the story is executed in stone only during 16th Century A.D. Not only that, this was the period when *peravar* heroes were portrayed in sculptures such as *Harirambadu*, *Chandramathi* and other folk people like *Kannan Karathi*, Snake Charmer and so on. These types of sculptures are found in *Vijayagangam* and *Nigut mastapa* elsewhere in Tamilnadu. On this basis too, we can identify the horse rider as *Chocka Ramethar*, the hero of an episode in *Thiruvilayadal Perumal*.

Authenticity on Style and Dating by Ornamentation

Any stone sculpture or bronze image can be differentiated from other by its style and ornamentation. For instance, if the *Yagnabhantha* of a sculpture crosses upon the right arm it is considered to belong to early *Pallava* or early *Pandya* style. If it passes below the arm, it is assigned to *Chola* or later *Pandya* style. More over, if the ornaments are very simple and minimum in

number, the figure may be dated to early *Pandya* or early *Pallava* period. Rich ornaments, cluster of dresses, and massive and physical features like muscles are found in a sculpture and then it could be dated to the *Ngah* period.

Authentication by Inscriptions

Inscriptions are the most reliable tools for not only writing history but also fixing exact date of any art object. Even in identification of sculptures also inscriptions help us with exactitude. For example, a *desampalaka* sculpture found now at Art Gallery, Tanjore in Tamilnadu 'contains an inscription on its pedestal. It gives us the full information regarding the *desampalaka* sculpture that it was brought by the *Chola* King *Vijaya Rajendra Deva* (*Rajadhi Raja* I 1018-1054 A.D.) as a war trophy when he destroyed *Kajjaputra*, the Western *Chalukya* Capital'. From this inscription we come to know exactly the name, style, origin and date of the sculpture.

Likewise, some foundation inscriptions are also found in some places from which the sculptures within that particular temple could be dated. For instance, an inscription dated to 773 A.D. reveals the installation of *Durga* and *Jyutha* sculptures in the cave temple at *Thirapparakundam* by one *Nakkas Keri*, the wife of a military general.⁸ In the same manner an inscription at *Anaimalai* near *Madurai* dated to 770 A.D. gives the authentic information about the execution of the *Narasimha* Cave Temple.⁹ The foundation inscription at the Great Temple, Tanjore, which appears as the personal statement of the King *Raja Raja I* stands testimony for the dating of the sculptures. At least twelve sculptures from a *Siva* temple at *Kilmaithur* near *Madurai* are dated to 12th Century A.D. on the basis of inscriptions found in the temple.¹⁰ Not only that, from these inscriptions the existence of the *Pallava-Pandya* art link was also discussed at length by the scholar.¹¹

But we cannot depend completely on the foundation inscription in dating the sculptures within the temple complex. Some missing links are also witnessed in certain places. Two inscriptions in *Kandam Isuram* (Now it is called as *Misakki Chokkanatha temple*) at *Anppakkattai*, *Virudhanganar* district in Tamilnadu, mention about the installation of sculptures *Lingapuram Devi* and *Durga*¹² in their respective niches during 1190-1216 A.D. But the two sculptures found today in the niches are not the original ones. Some how, they seem to have been replaced with the later period specimens (17-18th Century A.D.).

Much care should be taken in such instances. In some rare instances, the name of the sculptor is engraved on the pedestal itself, which provides authenticity in identification. We get such specimens from *Kyakkai Margalaar* in *Tirunelveli* district in which names like *Sathakruthaba*, *Kyaka* and *Budaba* are engraved¹³.

Inscribed Sculptures

Fortunately, a handful of sculptures have been found so far in the *Puducherry* region in which inscriptions are engraved on the base of the sculptures. These inscriptions provide more authenticity in identifying and dating the sculptures. Recently, in one the explorations, an inscribed *needhi* (bull) sculpture is found at *Naras* village in *Kamandi taluk*, *Ramanathapuram* district. The inscription is in *Vatteluthu* character datable to 10th Century A.D. and reads as "*Sri Kattibhak Kanti Senthai Vappatha Irubhai*"¹⁴. This *needhi* was installed by *Senthai*, a dancer by profession who was conferred with *kanti* title. Previously an inscribed stone slab has been discovered¹⁵ in the same place in which the existence of a *Siva* temple during the



*Inscribed Needhi Sculpture 10th Century A.D.
Naras, Ramanathapuram District*

period of *Vijayapada* who took Chola's head (946-963 A.D.) is known. We can fix the date of the inscribed *sandis* also corresponding with that inscription.

A Jain Thirthankara sculpture also contains an inscription on its base, which provides information when and by whom that image was installed¹⁶. The image is found at *Pandakudi* village situated in between *Aruppukottai* and *Elayaperum* in *Tirunelveli* district. From this inscription, the date of the sculpture is fixed authentically as 1007 A.D. and *Pahal Sadjas*, a Revenue Officer, installed it.

An inscribed lion figure, *Vahana* of *Durga*, is found in a village *Theppilakkur* in *Virudhunagar* district. This inscription also gives the date and the person who installed that figure. This lion figure was installed by *Vivek Sadakkar* alias *Dharmaradhakar* during the 28th regnal year (1098 A.D.) of the Chola King *Kalaburga I*¹⁷. An inscribed sacrificial altar, *kub pitam*, was also found nearby the lion figure, which can be dated to about hundred year later than the lion. It was instituted by *Irattabamas* alias *Tamilathangas* during *Kalanegara Pandya's* reign, 13th Century A.D.¹⁸.

Two more sculptures, one *sandi* and an altar are discovered at *Mazuvir Perunkudi* in *Virudhunagar* district in a recent survey¹⁹. On the pedestal of the *sandi* figure, the information regarding the installation is engraved from which we came to know that the figure was placed during the 3rd regnal year of *Marumamas Jandara Pandya I* who took the *Chola* country (1218 A.D.). The inscription engraved on the altar found near the *sandi* figure mentions that the altar was installed by *Piruvu Vayyar* of that village. *Piruvu Vayyar* refers to a group of personal security force of the king. This inscription can be dated to 13th Century A.D. on paleographic grounds. Still there is much scope to discover such inscribed images in the same *Pandya* region in the future explorations.

Conclusions

By the above-discussed facts, it is confirmed that inscriptions are the most reliable, authentic source than any other literary, legendary and *agamir* sources. Not only the identification and dating of the sculptures are arrived, but also inscriptions can draw the social history and art history. Proper steps are to be taken in tapping the inscriptional sources to reconstruct our history in all possible areas. By all means these sculptures should be preserved for posterity.

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Some Early Period Stone Sculptures of Chennai Museum

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The Government Museum, Chennai has a good number of fine stone sculptures, collected from various art centers of South India. They range from 2nd Century B.C. to 18th Century A.D. and represent most of the leading major and minor South Indian Art Schools. These sculptures are made with a varieties of rocks found in South India. Recrystallised limestone, granite, quartzite – feldspathic rocks, green stone, chloritic schist and magnesian schist have been used to sculpt the statues.

Amravati Sculptures

The *Amravati* Sculptures housed in the Buddhist Gallery in Chennai Museum form the cream of its sculpture collection. This soft, fine-grained rock is pale green in colour and is referred as "Palnad Marble" by the Indologists and art historians. These type of rocks are composed of calcite. Richard Newman of Harvard University has conducted a sample survey of Indian rocks. From his study we learn that the grain sizes in the *Amravati* sculptures are in the range of 0.01 – 0.03 mm. Their neighbouring crystals show irregular polygonal grain boundaries. They contain quartz, mica and zircon grains.

Pallava Sculptures

The fine life size seated *Vishnu* and a bust of a horned *Dvarapala* from *Kanarpakkam* in the *Pallava* bay in the Main Buildings are good specimens for the *Pallava* Art School. *Kanarpakkam* near Kanchipuram yielded a good number of *Pallava* and *Pallava* – *Chola* transitional period (8-9th Century A.D.)

Sculptures. The *Padmanabhi*, *Jaganathi* and *Incres* of dwarfs all from *Kaveripakkam* are excellent works. Seated *Dakshinamurti* from the same place is another good *Pallava* image. The *Saptamatruka* group of sculptures from *Sajumangalam*, displayed in the Hindu Sculpture Gallery also belongs to this period. The small sculpture of *Gopalakrishna* again from *Kaveripakkam* is unique for its iconographical features. The figure of *Gopalakrishna* is carved on a slab. She is flanked by two elephants, two lamps and two *asur* (*Jaganathi* and *Padmanabhi*) are also shown. Thus we find a combination of many auspicious objects along with the figure of goddess *Lakshmi*. The hands and legs of these goddesses are shown as curled up at sides and thus the form of *Janata* is symbolised.

St. Thomas Mount and the adjoining hills seem to be the source for the *Pallava* sculptures. Though *Pallava* preferred sandstone for their temple construction, charnokite rocks also had been used by them to carve freestanding sculptures.

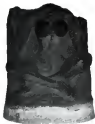
Kanchipuram Sculptures

The *Pallava* period sculptures, in the Chennai Museum have been collected from places like *Kanchipuram*, *Mahabalipuram* and *Kaveripakkam* and their surrounding areas. *Kanchipuram* was the capital city of the *Pallava* kings. Even after the hegemony of *Pallava* kings, *Kaveripakkam* continued to enjoy the status of cosmopolitan city and a great cultural centre. The *Kannan* sculpture in the Hindu Sculpture Gallery is considered as one

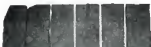


Dakshinamurti

that has come from *Kanchipuram* area. On stylistic grounds, the image is assignable to early *Chola* period (c.9th Century A.D). The seated image with four hands identified as *Kaamar* belongs to the group of eleven sculptures of *Saptamatrka* set of a temple complex. Prof. Gabriel Journeau Duhrout (1885–1945) and his associate, M. Thangavelu found these sculptures in 1926 in the environs of *Kanchipuram* close to a tank. Prof. Journeau Duhrout and R.B. Whitchhead had identified the female images of this group as *Aharahantgar* on the basis of folk tradition provided at that time among the villagers of *Tamil Nadu*. But scholars of later period tend to see them as of *Yogini* or of *tantric* cult.



Kaamar



Saptamatrka

Except *Kaamar* sculpture in the Government Museum, Chennai, all other sculptures collected by Prof. Journeau Duhrout near the tank in *Kanchipuram* were shipped by him to

Paris in the late 1920. From Paris they were widely dispersed to various museums in Europe and U.S.A. Now they are found in the following places:

1. Detroit Institute of Art, (Detroit, Kansas City, U.S.A.)
2. Minneapolis Institute of Art, (Minneapolis, U.S.A.)

3. Museum of Fine Art, (Boston, U.S.A.)
4. Arthur M. Sackler Collection, (U.S.A.)
5. British Museum, (London, U.K.)
6. Musée Guimet, (Paris, France)
7. Royal Ontario Museum, (Toronto, Canada)
8. Rielberg Museum, (Zurich, Germany).

Richard Newman of Harvard University has studied one of these *Kanishpuram Saptamatruka* set of sculptures to discern its petrographic details. The *Chettai* (Jeyshita) sculpture of Arthur M. Sackler Collection given on loan to Brooklyn Museum was studied by him. Richard Newman has identified the kind of stone used to sculpt the image of *Chettai*, as green schist, a metamorphosed basic igneous rock. Green schist is otherwise referred as green stone. The Chennai Museum *Kaamar* sculpture also seems to be made of green schist.

Chola Sculptures

Chennai Museum has a good number of *Chola* sculptures in the *Chola* bays, in the ground floor of the main building and in the Hindu and Jain Sculpture Galleries. They were collected from areas in South Arcot, Thanjavur and Pudukkottai districts. Though the image of *Sabramanya* in the Early *Chola* bay is badly mutilated, it does not fail to reveal the richness of its carving. The *Bhokabata* and *Tripurantaka* with *Tripuravandana* are the best examples for Early *Chola* period workmanship.

Most of the *Chola* sculptures in the museum are sculpted in granulite (metamorphic rock consisting of quartz and / or feldspar and dark coloured magnesium - iron silicates, formed under very high temperature and pressure conditions). Granulites are otherwise known as charnokite. In composition it ranges from granite - granulobelite to monzonite to diorite.

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The Role of Curators in Preserving Stone Sculptures

N. Soundrapandian,

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Museums preserve art and cultural heritage for posterity. Curator in a museum has multifarious activities including taking care of the collection. He has to interact with conservators for the proper upkeep of the objects in case they need conservation care. Among the various medium, any museum has more collection of stone objects.

Normally, stone objects are very durable, but in unfavourable circumstances even they can deteriorate. Presence of soluble salts, absorption of water, growth of moss and lichen, careless handling are some of the factors dangerous to them.

Salt action is very dangerous to stone objects. Salts absorbed by stone objects get recrystallised and crumbling of surface takes place.

As a precaution against rise of water by capillary action, stone objects should never be displayed by embedding parts of them in the ground or in brick and cement masonry pedestals as water finds its way from the ground to the stone.

Though sculptures are durable as they appear, they start crumbling and showing signs of cleavage. The Curator is often baffled. Protective coatings and location of the stone sculpture are going to help, unless the root cause i.e., the direct passage of salt water to the sculpture is remedied. Extraction of salts from the stone will not be of any help either, because they will reappear again in solution with the rising capillary water. Therefore, wooden pedestals are better, because they prevent the rise of moisture.

Stone sculptures can be placed on brick and cement masonry pedestals, if a moisture – barrier, like a plastic sheet or lead sheet is inserted in to the pedestal just above the ground.

Stone sculptures often get accumulated dirt or stains. Loose dust can easily be brushed off. But even for stone, a soft brush is recommended and the practice of whipping a stone sculpture with a duster cloth should not be allowed. Plain water can wash away most of the accretions. Sometimes, a mild detergent in water can be used. Acids should never be used to clean stone, except by a trained conservator, who understands their action on various types of stone. Grease, oil, paint or wax can be cleaned with organic solvents of appropriate type.

There may develop a deposit of moss and lichen on stone objects especially those, which have remained in the open for some time. Such a deposit is not only ugly in appearance, but also produces pits in the surface of the stone and may weaken its structure. A trained conservator should be able to remove the moss and algal deposits easily. A collection Curator should not try to do this job himself as it involves the use of chemicals, which are dangerous.

The question whether to coat a stone object with a protective coating is often raised. Normally it is not advisable to apply any such coating, unless absolutely necessary.

Handling of stone sculptured pillars and other objects and their shifting from one place to another is probably more difficult than that of other types of material because of the weight.

The best way to lift heavy objects is by mechanical fork-lifts and to move them by trolleys. A fork-lift however is costly and all museums may not be in a position to own one. As an alternative, strong ropes may be tied around the object and required number of persons may lift it to the trolley and even carry it suspended using a pole. In that case it is absolutely necessary to have proper admissible padding between the rope and the object otherwise it will be abraded.

Care should be taken to cover stone objects with sheets of polythene or atleast cloth sheets, so that no paint drippings splash on them. Very often it is difficult to remove paint stains completely from the stone as it penetrates into its pores.

Curator has to understand the nature of stone and stone objects should never be piled one over the other. Scratches will be made and sometimes they may be damaged severely.

Sculptures, Role of Curators in Preserving Stone Sculptures, Pottery and Ceramics

Always use gloves while handling marbles, pottery and ceramics. Special attention is needed in lifting and carrying these using sufficient soft padding.

Examine for any powdery formation or salt formation on pottery, it may be salt, consult a chemist about it immediately, otherwise it may be harmful to remain on it.

Marble is easily stained, hence packing and padding materials should be dry and cleaned.

Although the shape of every individual sculpture will dictate the safe position in which it should be moved, yet the sculptures are transported generally in horizontal position and not in upright position.

Any chipped off or broken fragments of a sculpture must be stored for further restoration.

While dusting or cleaning do not whip or rub cloth on marble, pottery etc., as it may go deep into grains, hence only gentle feather brushing or vacuum cleaning should be done.

Do not undertake cleaning or joining without proper expert consultation or trained hand attending to it.

Pollutants

Industrial waste gases contain oxides of sulphur, carbon and nitrogen, which are extremely harmful to museum objects. Paper,

textiles, leather, even metals and stones deteriorate more rapidly in a moist atmosphere containing oxides. These gases are converted into acids, which damage most materials. The only effective way to remove oxides from museum air is to pass the air through an activated carbon filter or through a water spray. This is possible only when the building is air-conditioned.

Conclusion

The care taken by a Curator is very important for the safety of the museum objects. Therefore, collection Curators must have a good knowledge of conservation principles. He should know the material science of the medium of objects for their preservation to posterity.

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Role of Museums in the Preservation of Stone Objects

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A museum was defined in the 1970s and even in the 1980s as a non-profit making permanent institution in the services of the society and of its development and open to the public, which acquires, conserves, researches, communicates and exhibits for purposes of study, education and enjoyment of the material evidence of man and his environment (the Statutes adopted by the 11th General Assembly of ICOM (Copenhagen, 14th June 1974), the 15th General Assembly (Buenos Aires, 4th Nov. 1986). But nowadays, museums are making profits just to ensure survival and development. The Metropolitan Museum, New York has started having exhibitions even on cosmetics just like multi-national corporations. Therefore, marketing has become an important part of museology. Museums are varied according to their type, historical, science, textile etc., and their activities are also varied.

Activities of a Museum

Collection, acquisition, documentation, preservation, conservation and display are the important activities in relation to objects. Education, research and publication are offshoot of the main activities relating to objects. A museum exists to preserve the objects of the past to see, enjoy and preserve them for the future. Preservation for display forms the most important activity in a museum. This activity is not only the duty of the staff of the conservation laboratory or conservators and restorers, but also the duty of every one employed in the museum.

Collection of Objects

Collection of objects is an important activity of a museum. There are various methods of collection. Each museum has its own collection policies depending upon its nature and management. Archaeological museums, anthropological museums, geological museums, multidisciplinary museums etc., have in their collections objects made of stone. The collections of stone objects in Indian museums are detailed here.

Methods of Collection

The many ways of collection of museum objects vary. Field collection, treasure-trove, gifts, purchase, loan, exchange, confiscation, transfer etc., are some of the common methods of acquisition of objects for a museum.

Field Collection

Field collection is very important in the sense that the locality of the object is known. The archaeology departments or the anthropological departments make an area survey. Surface collection is made in most of the areas. A good scan will reveal many objects such as coins, beads and potsherds.

An anthropologist surveys tribal areas and collects objects. A geologist collects minerals, rocks, slabs, fossils etc., as surface collection from different areas. Depending upon the interest, the collection increases through field collection. Archaeological collections such as sculptures, stone inscriptions can be collected only by government museums, as the permission has to be got from the Collector of the district under the Indian Treasure-trove Act. A group of students may be taken to the field for practical study and objects collected. Visiting various quarries and regions where specimens are available also makes for good geological collections. Fossils are also available sometimes when digging in the quarries.

Role of Museums in the Preservation of Stone Objects

- R. Kannan



Mustard Balidhatana from Hampi (Gowris)



Mixing Portion of the Hoysaleswara Period: Carved Stone Door and Columns Resembling Visually Similar Looking Wood



Inauguration of the Capable Course on Conservation of Cultural Heritage by Mr. P. A. Ramulu, I.A.S., Secretary to Government, Tamil Nadu Development-Culture and Industries Department, Dr. V. Jeyan, Mr. K. T. Narasimhan, Superintending Archaeologist, Archaeological Survey of India, Chennai, Dr. R. Kannan, I.A.S. and Mr. A. Abdul Majid, Former Director of Archaeology are on the Day.



Mr. G. Nandhi Kumar, I.P.S., Additional District General (Economic Officer) Delivers the Voluntary Address of the Capable Course on Conservation of Cultural Heritage, Dr. V. Jeyan, Mr. C. S. Jayaramanathan, Former Assistant Superintending Archaeologist Chennai, Mysore, Dr. R. Kannan, I.A.S., Mr. N. Hanumantham, Former Director of Museums and Mr. K. Lakshmanaprasad are on the Day

Report on the Activities of the Chemical Conservation and Research Laboratory



Mr. G. B. Jayaraman, former Assistant
Superintendent Archaeological Officer, Mysore
Delivers a Lecture on Chemical Cleaning of Stone
Monuments. Dr. R. Ramani, Mr. K. Lakshminarayana
and Dr. V. Jayaram are in the Fore.



Mr. G. B. Jayaraman, former
Assistant Superintendent Archaeological Officer,
Mysore Treating Chemical Cleaning in a Temple



Officials are Chemically Cleaning Stone
Pillars in a Temple



Officials are Chemically Cleaning
Moss and Lichens Affected
Temple Compound Wall



MSB Students Clean Stone Sculptures in the
Archaeological Gallery



International Workshop on Metal Conservation

Excavations

Excavation is a scientific method of revealing the buried objects under earth. Excavation is one of the methods of acquisition of stone objects in the museums. Some museums are empowered by the Government of India to undertake excavation if they have qualified archaeologist and add the objects thus obtained in the collection of the museum. Chennai museum once excavated and objects were acquired. In India, no department can undertake excavation unless permission is obtained from the Director General of Archaeological Survey of India.

Treasure-trove

According to the Indian Treasure-trove Act, the buried objects when found belong to the government. The Collector informs the head of the department of museums who acquires it for the museum after examination. Compensation is given to the person who found the treasure as well as the owner of the land. Such facilities are available only to the government museums. The Government Museum, Chennai is augmenting its collection through the Treasure-trove objects. The important additions to the bronze collection are the Buddhist sculptures from *Nagapattinam*, *Vilankanni Natongis* etc.

Gifts and Bequests

The British Museum came into existence by the bequest of Sir Hans Sloane. Fitz William Museum was born by the bequest of the Count Fitz William of Cambridgeshire. It is difficult for any progressive museum to fulfil the desire of the donor to exhibit all his material at one place or to keep them on display at all times. Salar Jung Museum is a museum established out of the collection of Salar Jung III and the gifts from well wishers and art collectors of the area. In Tamil Nadu, many gifts are received from local supporters and benefactors to the museums. Some organisations also collect objects and give them as gifts.

Purchase of Objects

Museums enrich their collections by purchase. The Curator purchases objects of the interest of the museum when he undertakes tour to different places. Larger museums have an Art Purchase Committee. Any object to be bought has to be evaluated by the Committee for its genuineness and value.

Transfer of Objects

Most of the government buildings possess antiquities. There is no provision for the preservation of the antiquities in their possession and also no trained personnel to preserve them. Therefore, government transfers the antiquities in buildings to the government museums.

Confiscation of Objects

Art and cultural objects from temples and other sites are illegally removed by contraband dealers and sold to foreign agencies. These objects are legally confiscated by the Idol Wing of the Police Department and handed over to the Court. Finally they are handed over to the museums department in Tamil Nadu. In this way the Department of Museums in the near past has received hundreds of bronze icons, sculptures and coins from the CBCID department.

Deposits

Museums at times get objects as deposits from the courts in India. Whenever antiquities are stolen from temples or private collections and are abandoned police take charge of the objects and are handed over to the Court. The Judge deposits the objects to the nearest museum. If the objects are ownerless, then the objects become museum property.

Loan of Museum Objects

Museums often receive objects both as short-term and long-term or permanent loan for a fixed period or indefinite period. The borrowing institutions have to maintain the objects in

good-condition and send an annual report on the condition of the objects. The borrowing institutions also inspect the condition of the objects loaned by its officers. The objects on short-term loan are for specific purpose such as special exhibitions or touring exhibitions. Some objects are loaned to other institutions on long term. In government museums, the loan is given only after getting necessary permission from the government concerned. Some stone objects from the Government Museum, Chennai are with the Raj Bhavan, Chennai on loan. Similarly some objects are loaned by the Archaeological Survey of India to the government museums.

Preservation Measures

Collection of objects itself is a preservation measure. If the objects are left in the place where they are found, they are likely to be lifted and sent abroad or damaged.

Acts to Preserve Antiquities

In 1863, when Lord Canning was the Governor General of India, the first Act to empower the government to prevent injury to and preserve buildings noted for their antiquity or for their historical or architectural value was passed. In 1878, the Indian Treasure-trove Act was enacted when Lord Lytton was the Governor General of India. In 1904, during the reign of Lord Curzon as Governor General of India, the Ancient Monuments Preservation Act, 1904 was enacted by the Government of Bengal. It was to provide for the preservation of ancient monuments, for the exercise of control over traffic in antiquities and over excavation in certain places and for the protection and acquisition in certain cases of ancient monuments and of objects of archaeological, historical or artistic interest. There were other Acts in the intervening years.

In 1972, the Antiquities and Art Treasures Act, 1972 was passed on September 9th, 1972 in order to cope up with the high occurrences of theft and illicit traffic in antiquities, which the

Antiquities (Export Control) Act, 1947 could not control. Following that, the Antiquities and Art Treasures Rules, 1973 dealt with a term "Art treasures", which are not antiquities within the meaning of the same legislation. The Antiquities and Art Treasures Act along with its Rules was enforced from 5th April 1976. An ordinance amending certain provisions of the Act was promulgated on 4th June 1976 and was made into an Act later in the same year without effecting any change in the provisions of the Ordinance or incorporating any new clause.

Museum Security

Museum security is a mechanism that provides for the protection of collections. Security is not only the job of security personnel but also it concerns every one who works at the museum and who visits the museum. Security is not just for the publicly accessible parts of the institution, but all other parts as well. Vandalism by visitors is a problem in the Government Museum, Chennai. Graffiti is written on the walls and periodically removed by the staff. Fines are imposed when the vandals are caught. Thankfully, no objects have been damaged so far.

Photography

Photography is one of the methods of preservation of any object in a museum. There are different types of photography viz. Black and white, colour, slide, x-ray, infra red, laser etc. The record of objects is very important. In case of theft of objects these photos will be of use to get them back.

Authentication

Antiquities are nowadays stolen and sent abroad. There are many examples of theft and exporting them to developed countries. Authentication is a very important aspect of preservation. There are many methods of authentication like x-radiography, making large patterns on objects etc. By all these means, internal defects in the objects are made as the mark of identification. The culprits

cannot identify the defects and even if they identify, they cannot create it in the new object they made replacing the ancient one. Tomography is a method of Finger Printing of Bronzes used in the Government Museum, Chennai.

Conservation of Stone Objects

Conservation is the job of a Conservator and the same can be done by a well-experienced collection Curator also. Every body in a museum has a role to perform in preventive conservation. It starts from a sweeper to the head of the department including the ministerial staff. The public has also some responsibility. Some objects are found damaged when they come to the museum or they get damaged in a museum. It is the duty of the collection Curator to interact with the Conservator or Conservation Curator and ensure that further damage does not take place. Sometimes the defects are rectified. This brings, therefore, the present philosophy of conservation rather than the philosophy of restoration, which prevailed earlier.

There are both physical and chemical means of conservation followed in the museum and it is the Conservator's job. Even if the museum does not have any laboratory, it can be done through private restorers, though the cost is prohibitive usually.

Limestone, Granite, Schist, Gneiss and Marble Objects

In the collection of the Government Museum, Chennai there are precious objects like the limestone sculptures from *Amaravati*, Andhra Pradesh. They get affected in the rainy season by moisture absorption due to *carrosis*, as they are embedded in the walls for the past 130 years. This is due to the rise in road levels in recent years. The museum has been using paper pulp treatment to treat such objects. Objects, which get affected beyond a point, are removed from the walls. It is proposed to shortly remove all these sculptures from the walls and remove them to safe storage and treatment. Then they will be redisplayed as in the *Asahi*

Shimshu Gallery in the British Museum, London using modern portable display stand techniques. This measure was mooted in the 1980s but has not been put into operation so far. Modern wooden or metal showcases preserve them from damage almost totally. However, a Curator of the British Library who was on a visit stated during the course of her lecture at the Government Museum, Chennai that they were in much better condition than those in Britain since those in London had been exposed to the unfriendly English weather and smogs earlier.

Granite objects are very hard and do not present many challenges for their preservation. They have been embedded on the walls or stood on special platforms. They have suffered no damage in the past 140 years. They are also displayed in the open-air Sculpture Park, a method now adopted in museums abroad. Though exposed to the elements, there is no deterioration till now. Oil accretions are however removed annually.

Mutilated sculptures present a different problem. Some like the famous *Balaubates of Hamps* on which I have written earlier are presented in their mutilated form. This is because the missing portions are not traceable. In other cases, where the missing parts are available they have been reconstructed, as they would have originally looked like. In earlier periods, missing portions were reconstructed using visually similar looking material as in the case of the *Hysala* carved doors and cornices. The original is of black schist, which is softer than normal granite, but the partial replacement is of wood, ebony. It is impossible to detect unless closely examined physically. The present philosophy is not to make such look alike replacements.

Like the *Hysala* schist, there is a Jun. Tirthankara sculpture, which is also black and looks similar. However, the stone in this case is gneiss. We have Buddha sculptures collected in present *Afghanistan* (Gandhara or *Kandahar*) and *Pakistan* (*Peshawar* etc). In both the cases, there is no perceptible deterioration on the scale

comparable to the limestone objects. There are no notable sandstone or soapstone objects in our collection.

The marble objects in our collection belong to the 19th and early 20th Centuries. There are only a few pieces like statues. They are in the reserve collection. There has been no deterioration of the stone. But some pieces are slightly mutilated. No reconstruction has been done in tune with the modern philosophy of eschewing such intervention.

Training

The first signs of deterioration are noticed by the collection Curator and his staff. Therefore, they should know elementary procedures of conservation. In our museum, cleaning is done periodically and any deviation from standard is reported to the Conservation Curator. The collection staff can also perform treatment like paper pulp treatment in consultation with the Conservation Section. This is a result of the training imparted to staff and others in preservation and conservation procedures. The Government Museum, Chennai is conducting many training programmes to give awareness on conservation among the museum personnel, Archaeologists, Executive Officers of the Hindu Religious and Charitable Endowments Department, Archivists, Librarians, students etc. Many workshops like this and seminars are conducted in museums. It is also a coincidence that the Max Mueller Bhavan has chosen a similar theme as that of the Government Museum, Chennai, which is conducting an International Seminar on Conservation of Stone Objects with Reference to Limestone Objects.

Chemical Cleaning of Stone Temple Walls and Sculptures in Lieu of Sand - blasting

This department has developed technical expertise in the area of chemical cleaning and made it available to other departments. The Hindu Religious and Charitable Endowments Department of Tamil Nadu is a major department, which takes care of over

30,000 temples. Most of the temples are ancient and the walls of the temples are clad with granite stone slabs. Pillars, sculptures etc., are mostly made of granite. Between the inner and outer veneer of granite slabs, the in-filling is made up of brickbats. The inscriptions, carvings, wall paintings, paintings on ceilings etc., are damaged by white washing, soot formed by the burning of camphor and lamps etc., application of oil, ghee, butter etc. Due to the leakage and seepage of water, moss and lichen and other cryptogamic plants affect the walls, ceilings etc. When they dry, they appear black and affect the stone by the acid formed due to the cryptogamic plants.

During the *Aambharubham*, a festive ritual renovation that is done usually once in 12 years, as a part of renovation of the temple, these accretions are removed by the temple authorities by sand-blasting. Sand-blasting removes the accretions along with the stone, paintings etc., besides damaging the stone. Once sand-blasting is done, the skin of the stone is removed. Further deterioration thereby diminishing the life of stone takes place. The Commissioner of the Hindu Religious and Charitable Endowments Department was requested by the author to abandon sand-blasting and use chemical methods of cleaning as an alternate safer method. The Commissioner of the Hindu Religious and Charitable Endowments Department, Mr. M.A. Govindhankar, I.A.S., studied the problem and instructed his subordinate officers to stop sand-blasting and adopt chemical cleaning as an alternate for sand-blasting. This order has saved hundreds of temples and Tamil heritage for posterity.

In order to provide technical expertise to the officials of the Hindu Religious and Charitable Endowments Department, it was decided to involve the Curators and Archaeologists of both the Department of Museums and the Department of Archaeology in extending consultancy or supervision of chemical cleaning of monuments. A week long Capsule Course on Conservation of Cultural Heritage was conducted at four centres namely, Chennai,

Madurai, Salem and Tiruchirappalli The participants of the course were mainly from Hindu Religious and Charitable Endowments Department, Department of Museums, Department of Archaeology, Southern Railway and Police Department. The trainees were exposed to various conservation principles related to antiquities and monuments, Acts pertaining to the protection of monuments and practical training on conservation of antiquities and monuments. The result of the chemical cleaning of walls, pillars and sculptures in the temples was excellent when compared to sand-blasting. This author personally participated in the manual cleaning. This programme was inaugurated at Chennai by Mr. P.A. Ramiah, I.A.S., Secretary to Government, Tamil Development-Culture and Religious Endowments Department and the Valedictory Address was delivered by Mr. G. Nandhi Kumaran, IPS, Additional Director General of Police, (Economic Offences) at Madurai. The training was organised by Dr. V. Jayaraj, Curator, Chemical Conservation and Research Laboratory of this Museum with the co-operation of experts like Mr. N. Hacinarayana, Retd. Director of Museums, Mr. C.S. Jayaramasundaram, Assistant Superintending Archaeological Chemist (Retd.), Archaeological Survey of India, Mysore, Mr. K.T. Narasimhan, Superintending Archaeologist, Archaeological Survey of India, Chennai Circle, Mr. K. Lakshminarayanan, Assistant Director, Government Museum, Chennai and Mr. M.S. Ashok Dhoeen, Chemist, State Department of Archaeology, Chennai. A list of consultants consisting mostly of retired archaeological chemists of the Archaeological Survey of India has been made available to the Hindu Religious and Charitable Endowments Department for giving technical advice for doing the work whenever any renovation takes place.

Conclusions

Museums have a very important role to preserve our art and heritage especially the stone objects to leave them without any defect to posterity to enjoy and preserve. The public also has

some responsibility to preserve them and give a helping hand to bring them to the museums and protect them. I believe that such seminars and workshops really make us to think further, to ponder into the subject to find out newer methods of preservation or conservation measures to preserve our treasures for an extended period of time.

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**Papers on
Conservation and
Restoration**

Stone Objects and Bio-Deterioration

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Suitable environmental condition and a good housekeeping protect the objects from the decay that would otherwise occur. Proper storage and display preserve any collection. To prevent deterioration of any object, the following should be taken care of:

For Inorganic Objects Like Stone

1. Climate – affected by wet, dry or hot climate
2. Temperature – makes the object to expand or shrink or split.
3. Growth of Biological Agencies – algae, fungi or lichens.
4. Air Pollution – presence of gaseous pollutants
5. Pollutants – Natural - seashore, suspended particles of salt, fungal spores. Man made – domestic, industrial, automobile.

Any deterioration of materials by biological agency is known as bio-deterioration. Stone objects are prone to be affected by lichens and bryophytes, which are biodegenerous. E.g. moss, liverworts. These produce the brown coloured rusty spots, called *foxing*, which is treated by bleaching. Chemicals such as potassium permanganate, oxalic acid, hydrogen peroxide or calcium chloride is used for the removal of foxing, depending upon the materials.

Factors Causing Deterioration

1. Physical Agents – light, heat, dust particles.
2. Chemical Agents – acidity, gaseous pollutants

3. Biological Agents

- a. Bacteria – grow on organic and inorganic materials
- b. Algae – grow on inorganic materials
- c. Fungi – grow mainly on organic materials
- d. Lichens – grow on inorganic materials
- e. Liverworts – grow mainly on organic materials

4. Accidental Agents – flood, fire, earthquake

Apart from this, there are two main factors

1. Internal Factors – Cracks, acidity, flaking, new handling
2. External Factors – Climatic condition, atmospheric pollution, light, physical factors, biological agents mainly algae, fungi and lichens

Stone occurs in nature as rocks, which are classified into:

1. Metamorphic Rocks – e.g. marble
2. Igneous Rocks – e.g. granite
3. Sedimentary Rocks – e.g. limestone

Rocks are aggregates of minerals. They are either 1. Monomineralic (calcite) – marble or 2. Bimineralic – granite (quartz + potassium feldspar). Limestone are non-clastic and marble is non-foliated.

Research in the field of Lichenology has revealed that stone objects and marbles are affected by lichens. Though lichen looks like a single organism, it is actually a symbiotic association between a photosynthetic organism e.g. a green algae or a cyanobacterium and a fungus, which is most often an ascomycete. In some lichens, in the tropical regions, the fungal partner is a basidiomycete. As part of the lichen, the fungus produces the fruting bodies. Most lichens produce lichen acids as secondary metabolites, which belong to chemical groups called depsides.

Crustose lichens are of primary importance and the acid produced by them brings about the disintegration of rock surface.

Lichens are remarkable group of primitive plants. Lichens are biological and not systematic group and each is basically a stable self-supporting association of a fungus (mycobiont) and an alga or cyano bacterium (photobiont). The dual nature of the lichen thallus was first proved by the Swiss Scientist, Schwender (1867-1868) and the relationship of the two components was termed by him as *lekition*, where the alga was the slave providing food to the fungal master.

There are approximately 15,000 - 20,000 lichen species. About 1/5th of all fungi are lichenized. Lichens are ubiquitous i.e. omnipresent plants that occur in a variety of habitats from the Arctic to the Antarctic regions of the world. They may grow on the bare rocks in the deserts, on tree trunks and on the grounds. They grow both in tropical and temperate climates.

Lichens, which colonise rocks, are called *Saxicolous* species. This lichen otherwise known as Crustose lichens are probably instrumental in initiating soil formation, either by secreting organic acids that weather the rocks on which they grow, or mechanically by the destruction of the rocks directly by the physical action of the lichen thalli.

Biology of the Symbiont

The dominant member of the lichen symbiont is usually the fungus and there is usually one fungus and one alga forming the lichen thallus. Ions dissolved in rain and from the deposition of dust meet the mineral requirements of lichen fungi. The fungus in return forms the outer cortex layers of a lichen thallus and also forms the rhizoidal hyphae, which absorb water from the environment and then transfers it to the algal layer. Close contact between a fungus and an alga was seen and intra-membranous haustorial penetration of the algal cells was demonstrated in *Ulexia rockii*.

Lichens are organisms formed by symbiotic association and integration between a fungus and an alga. The lichen thallus shows no resemblance to either partner. Their complex integration eluded Scientists for long, which considered them as single autonomous organisms. Lichens are identified and named by their own morphology and not on the basis of the component algae or fungi. Since the fungi and algae that form the lichen are organisms in their own right and genetically themselves, they deserve their rightful place in fungal and algal taxonomy.

The lichen symbiosis is mutualistic. The fungus derives carbohydrates from the algal partner, which in turn receives water, minerals and protection against desiccation and lethal light radiations from the fungus. Some however, believe the lichen association to be a case of controlled parasitism. The association involves complete integration and formation of a morphologically new thallus. The two components are individually incapable of free existence in nature.

Distribution of Lichens

Lichens grow in varied types of environments including such extremes as hot deserts and chilly mountain tops. One example of their resistance to extreme cold is the report (Scholander *et al.* 1953) that specimens frozen in liquid oxygen at -183°C for 18 hours resumed after thawing. Similar resistance is reported by Laege (1953) against extreme heat and prolonged drying. *Cladonia pocillum* could survive exposure to 101°C . Lichens survive long periods of drought. Lichens cannot withstand air pollution and therefore by their absence they serve as indicators of air pollution. Lichens colonise rocks.

Identifying lichen fungi is a difficult task, as they do not produce spores. Compared to other fungi, lichen fungi grow extremely slow in culture. The fungus is a Pyrenomycoete in a few lichens and a Basidiomycoete in one or two species.

The Lichen Thallus

The fungal partner apparently plays the major role in determining the form of the lichen. On the basis of their forms they are of four major types:

Crustose lichen : They are thin flat, crustlike thalli lying closely appressed to the substratum (trees, rocks or soil) Eg. *Graphis*

Foliose lichen: It is a flat thall with leaf-like lobes Eg. *Physcia*, *Parmelia*.

Fruticose lichen: Highly branched or cylindrical and are either erect or pendent. Eg. *Cladonia*, *Usnea*

Squamulose lichen: They are scale-like composed of many small lobes or squamules. Any particular growth form is not necessarily confined to a genus. In *Cladonia*, the basal part of thallus is squamulose, from which arise fruticose, simple or branched structures on which are borne the ascocarps.

Conditions that Favour the Growth of Lichens

The lichens need a low light intensity, cool temperature and moisture. The thalli behave like agar gel and absorb moisture from the humid environment in amounts up to 100-300 times more than their dry weight. The symbiotic relationship is much more advantageous to the fungus than to the alga and this kind of symbiosis where one of the partners stands to gain to a greater degree than the other one is known as *Helotism*.

The order *Graphidales* includes mostly tropical lichens, forming Crustose thall with green photobionts. The *Deuterolichens* are mostly sterile lichens in which sporocarps are unknown. The thallus varies from Crustose to Squamulose. These are found growing on soil rocks and trees.

Crustose lichens are the slowest to grow whose size and general appearance, remained unchanged for twenty years. Maximum yearly growth of 4.5 cm per year has been recorded for *Peltigo*,

paretectata, a foliose lichen. The slow growth of lichens are said to be due to the following:

The environmental factors to which they are exposed, permit only brief periods for optimal metabolic activity. 2. The intrinsic slow growing nature of the component symbionts.

Reproduction in Lichens

Asexual Reproduction

1. By fragmentation of the thallus, which may be natural.
2. By Soredia, which consists of few algal cells wrapped in hyphae. These are disseminated by wind.
3. By Isidia. These are stalked outgrowths of the thallus, which are separated only by accidental breakage.
4. By Conidia. Their role in forming new thalli is negligible.

Sexual Reproduction

Several lichens of *Physcia*, *Parmelia*, *Usnea* and *Cladonia* form distinct apothecia born on long stalk. The fate of the Ascospores is not known. The algal partner does not show sexual reproduction.

Lichen Acid

Most lichens (except gelatinous and some others) produce lichen acids as secondary metabolites. The distinctive colour of lichen thall is due to some of these acids. In sections, coloured lichens show crystals of these acids deposited on the fungal hyphae, which are easily extractable. Most of the lichen acids belong to chemical groups called depsides and depsidones, which are condensation products of 2 or 3 p-phenyl carboxylic acids, mainly *orsellinic* or *B-orsellinic* acids, held together by an ester linkage. It is known that these aromatic acids are formed by the mycobiont and the ester linkage is provided by the 'Phycobiont'.

Importance of Lichens

Crustose lichens are of primary importance in the colonisation of rocks. Acids produced by some of them bring about disintegration and erosion of rock surface. Minerals that are released are utilised by the lichen, which get a foothold on the barren rock. Their death and decay provide nutritive ground for the growth of other lichens and mosses, which extend the colonisation. Thus lichens have long been the subject of biological investigations because of the intriguing nature of the association between a fungus and an alga.

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Lichens on Indian Monuments: Bio-deterioration and Remedy

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Monuments are the few relics of our past that have defied the destructive forces of nature due to their strength and tenacity. They form part of our history and speak about our cultural heritage. These monuments are invaluable assets of the country they belong to. The UN has declared nearly 721 sites world over as World Heritage Sites and 23 of them occur in India and 16 of them are of archaeological interest. These sites are protected by international treaties. The recent destruction of Bamyan Buddha statues by the Afghan rulers received worldwide condemnation. These reflect the world's commitment and interest on the historical monuments. And for these reasons, the monuments in different locations of the country must be protected from all the damaging factors. We have inherited these monumental assets from our forefathers and it is our prime responsibility to pass it on intact to our future generations.

The main threats to these cultural heritages are from the biological agents especially higher plants, algae and cyanobacteria, fungi, lichens and bryophytes growing on them. The first and foremost invasion on these subjects of archaeological interest is from the lichens. Lichen species use monuments as their substrates. The role of lichens in transforming rocks to soil is considered as a beneficial process in soil formation. However, it is a threat and not welcomed on monuments. Since the outer surface of monuments needs to be preserved in its original form, the outer surface seldom receive white washing etc., as well as

lede disturbed. Thus lichens colonise and grow luxuriantly on these surfaces. Eradication of lichens from monuments minimises damage to them.

The Lichens

Lichen is a symbiotic association between an alga or a cyano bacterium (photobiont) and a fungus (mycobiont), the resulting phenotype neither resemble the partners. The symbiotic nature of lichens has provided them certain advantages like ability to colonise, vast spectrum of habitats and substrates, adaptive growth forms, effective reproductive and dispersal mechanisms, prolonged longevity, slow growth rates and an array of secondary metabolites with specific ecological functions. Lichens with these adaptations are able to colonise and grow on substrates that are relatively stable and monuments provide them the excellent substrates to grow. Normally, lichen growth is indicative of unpolluted atmosphere, but on monuments it becomes unwanted because it causes damage and deterioration.

The lichens disfigure monuments by over growing and spoil the aesthetics, disfigure finer details due to physical damage and interact with their secondary metabolite constituents on the substrate and solubilise them.

The crustose lichens, for their firm attachment and intimate connection with the substratum are very efficient and dangerous rock corroding agents. They are liable to cause greater degree of biodeterioration to monuments than foliose and fruticose forms. The crustose lichens attach themselves by mycelium penetrating the substratum. Crustose species belonging to Physciaceae, Teloschistaceae, Lecanoraceae, Peltolaceae etc., cause extensive damage to the substratum. Lichen species *Caloplaca* has a characteristic orange – yellow colour that modify the original colour of the monument's surface. Species of this genus can withstand high light intensity and heat due to the presence of Trebouxiooid photobiont and light screening compounds like

panettin within them (Plate1, figs.1&6). This substance is also known to solubilise the rock particles.

The foliose lichens belonging to Physciaceae, Parmeliaceae, etc., were able to colonise and cover vast surface area of the statues and monuments with root like structures called rhizines. They are loosely attached to the substratum and can be easily removed using scalpel or a sharp knife other than using chemical agents to remove the lichen thallus. These lichens also leech out lichen acids in to the substratum and disfigure them.

There are only a few reports on lichen-induced damage to Indian monuments (Singh *et al* 1999). Studies reveal a number of disfigured statues by lichens, many a times the finer details of statues, delicate carvings and inscriptions being obliterated. Some cases of biodeterioration of monuments also has come to light. The monuments were found undergoing physical and chemical damages by the lichen growth. The list of lichens colonising Indian monuments are given in the following Table 1.

Table1: List of Some Important Lichen Taxa Observed on Indian Monuments (Bajpai *et al* 1999, Singh *et al* 1999 and Chatterjee and Singh, 1999)

Lichen taxa	Family
<i>Berlita postulata</i>	Physciaceae
<i>Berlita</i> sp.	Physciaceae
<i>Calyptra</i> sp. (4 types)	Teloschistaceae
<i>Candelaria cuneata</i>	Candelariaceae
<i>Cladonia rumicra</i>	Cladoniaceae
<i>Coccocarpus palmicola</i>	Coccocarpiaceae
<i>Diplaziatia reginae</i>	Thelotremaaceae
<i>Dirinaria confinis</i>	Physciaceae
<i>Dirinaria conimili</i>	Physciaceae
<i>Dirinaria papillulifera</i>	Physciaceae

Stone Objects and Bio-deterioration

-M.N. Pruthi

Lichens on Indian Monuments: Bio-deterioration and Remedy

-P. Balaji and G. N. Haribanan



Buellia sp., Plymouth,
St. Thomas Museum



Leichen, a Maralene Association of
Fungi and Algae on Conchobates
Sometimes Occur as a Colossal, though
Crusty Growth on Bare Rock Surface



Acetabularia sp.



Buellia homophylla



Buellia miniata



Calophlyx pilosus



Calophlyx sp.



Chrysothrix chlorina

*Lichens on Indian Monuments:
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Lecanora ramosa



Lecanora sp.



Parmotrema praenorsellum



Peltula perulata



Pertusaria sp.



Phylloporus testaceorum



Phaeodictyon sp.



Pyrenopeziza sp.

<i>Endocarpon nannum</i>	Verrucariaceae
<i>Endocarpon parvum</i>	Verrucariaceae
<i>Heterodermia hypoceras</i>	Physciaceae
<i>Heterodermia incana</i>	Physciaceae
<i>Heterodermia leucocolla</i>	Physciaceae
<i>Heterodermia micropycilla</i>	Physciaceae
<i>Lecanora</i> sp. (5 types)	Lecanoraceae
<i>Leprosia</i> sp.	Leprosiaceae
<i>Leptogium indicum</i>	Collemataceae
<i>Leptogium picturatum</i>	Collemataceae
<i>Parmelinella wallichiana</i>	Parmeliaceae
<i>Peltula exilis</i>	Peltulaceae
<i>Peltula petiolata</i>	Peltulaceae
<i>Phyllocolpa indicum</i>	Lichinaceae
<i>Phyllocolpa inae</i>	Lichinaceae
<i>Physcia plana</i>	Physciaceae
<i>Physcia trebouxii</i>	Physciaceae
<i>Pyxine acuta</i> var. <i>acuta</i>	Physciaceae
<i>Pyxine acuta</i> var. <i>prominens</i>	Physciaceae
<i>Pyxine petriola</i> var. <i>petriola</i>	Physciaceae
<i>Pyxine petriola</i> var. <i>pallida</i>	Physciaceae
<i>Rocella montagnei</i>	Roccellaceae

Dominant Lichen Families and Growth Forms on Indian Monuments

The lichen family Physciaceae mainly species belonging to *Physcia*, *Dimaria*, *Pyxine* and *Baeisla* are dominant over the Indian monuments. These lichens are equipped with secondary metabolites like stromatin, lichexanthone, norstictic acid, divaricatic acid etc., and Trebouxoid photobionts to withstand

high light intensity as well as to grow under extreme heat and difficult substratum like that of stones (viz. monumental surfaces). Verrucariaceae and Teloschistaceae are also prefer to colonise the monuments. Only few species belonging to the lichen families Candelariaceae, Roccellaceae etc., colonise the monuments. The foliose lichens are dominant on monuments followed by crustose and squamulose forms. The leprose and fruticose forms were less on Indian monuments.

During our field visit to the monuments in Tamil Nadu like Rock-cut Temples of Mahabalipuram (near the by-pass road), Tirukkalukundram (*Orekal Mandapa* Rock-cut Sun Temple of the time of Mahendravarman I, A. D. 610-640), Gingee Fort (Gingee is famous for its 13th Century Fort between Thanjavur and Tiruvannamalai in Tiruvannamalai district on the 3 different hills summit covering 3 km boundary area; terracotta work of Ayyavir temples in Pudukottai district and few local ancient temples in and around Chennai city we were able to observe the following lichen species on these monuments (Table 2).

Table 2: Lichens of Tamil Nadu (India) Monuments
(Refer Plate 1 & 2)

Location	Lichen	Family	Photobiont
Mahabalipuram	<i>Acarospora</i> sp.	Acarosporaceae	Trebouxia
Mahabalipuram, Tirukkalukundram	<i>Buellia</i> <i>hemisphaerica</i>	Physciaceae	Trebouxia
Mahabalipuram, Tirukkalukundram	<i>Buellia</i> <i>arconoides</i>	Physciaceae	Trebouxia
Tirukkalukundram	<i>Buellia</i> sp.	Physciaceae	Trebouxia
Mahabalipuram	<i>Calophasia</i> <i>pulchra</i>	Teloschistaceae	Trebouxia
Mahabalipuram, Tirukkalukundram	<i>Pyxine minuta</i>	Physciaceae	Trebouxia

Location	Lichen	Family	Photobiont
Ganges	<i>Pyxine</i> sp.	Physciaceae	Trebouxia
Ganges, Mahabalipuram, Tirukkalukundram	<i>Petrula parviflora</i>	Petrilaceae	Cyanobactera
Ganges, Mahabalipuram	<i>Phyllocum testudinum</i>	Lichanaceae	Trebouxia
Tanjore	<i>Chrysothrix chlorina</i>	Chrysothamnaceae	Trebouxia
Tirukkalukundram	<i>Lecanora</i> sp.	Lecanoraceae	Trebouxia
Tirukkalukundram	<i>Pertusaria</i> sp.	Pertusariaceae	Trebouxia
Mahabalipuram	<i>Pertusaria</i> sp.	Pertusariaceae	Trebouxia
Temples of Chennai	<i>Phyllocum testudinum</i>	Lichanaceae	Cyanobactera
Temples of Chennai	<i>Buellia</i> sp.	Physciaceae	Trebouxia
Temples of Chennai	<i>Verrucaria</i> sp.	Verrucariaceae	Trebouxia
Terracotta work in Padukotta district	<i>Placodium</i> sp. <i>Verrucaria</i> sp.	Parmeliaceae Verrucariaceae	Trebouxia

Mode of Action by the Lichens on Monuments

Physical damage to monuments occurs mainly due to the growth of crustose and squamulose species. These species undergo shrinkage and expansion of thallus in different moisture regimes. During expansion of the lichen thallus, it adheres closely to the substrate particles, and during contraction these particles get pulled out from the substratum and flown away by wind action. In initial stages this physical damage may not be visible but in prolonged stages the damage is greater. The common lichen species found on monuments of Tamil Nadu are *Buellia*,

Caloplaca, *Lecanora*, *Pertusaria* (crustose), forms like *Endocarpon*, *Peltula* and *Phyllocium* (squamulose), *Physcia* and *Pyxine* (foliose).

Overgrowth of Lichen Species on Monuments occur as colonies of *Parmelia* sp. and *Physcia* sp. form mats over the monumental surfaces. This mat masks the sculptural external details of the monuments. However, some consider that this overgrowth also act as a protection from excessive sunlight and similar external factors. Since the lichen species thriving on lime or cement plaster of walls and roofs of buildings have, on the other hand, not only remained unaffected by atmospheric pollution and change of climatic conditions of the city but have shown marked tendency for an increase in their population. It is because of the invasion by these lichens on the largely increased substratum area provided by continuous building activity. This anomaly can be explained in the light of the observations of Leblanc & Rao (1973), who have shown the significance of substratum on the metabolism of lichens. They mention that lichens growing on alkaline substrate are protected from the ill effect of acidic gases that form considerable part of pollutants of the atmosphere. In this regard, they state, such a substrate in SO_2 polluted environment may represent a special niche, which though physically exposed to pollution, possess an in-built chemical protection from it (Singh and Upen, 1984).

Secondary Metabolite Mediated Damage

Many lichens produce secondary metabolites that are acidic in nature. These substances like lecanoric acid, oxalic acid etc., have the ability to corrode the substratum. Almost all the lichen species listed in Table 1 & 2, contain a rich array of secondary compounds.

Eradication of Lichen Growth on Monuments

Physical Removal: The foliose and fruticose lichen species can be removed easily by using a sharp chisel or a scalpel. However,

care should be taken while removing the thallus from the substratum without any damage to the monuments. The regular maintenance of the monuments like cleanings the outer surface, white wash and painting help to prevent further recolonisation of lichen growth over the monuments.

Chemical Treatment

Lichen growth can also be eradicated by spraying common biocides used in agriculture. Some of the effective biocides to control lichen growth were given in Table 3 (Bajpai *et al.* 1999).

Table 3: Effective Biocides to Control Lichen Growth

Biocides	Crustose	Foliose	Fruticose
Paraquat dichloride	1.0 (40%)	1.0	1.0
Polycide	1.0	1.0	0.5
Duron	1.0 (40%)	1.0	No effect
Benzalkonium chloride	1.0	1.0	0.5
Sodium penta chlorophenate	0.5	0.5	0.1

Other than the biocides, a very few chemicals are used to resist the lichen growth on monuments; they are liquid ammonia (5%) and zinc silico fluoride solution (2% and 4%). These commercial chemicals used in the conventional conservation practice in India for eradication of the general organic growth thus seem to be quite effective against lichens also (Bajpai *et al.* 1999). These chemicals were tested over the lichen sp. like *Parmentaria apiculata*, *Ulex subflorata*, *Parmentaria tinctorum*, *Heterodermia divaricata* var. *haryana* and *Aspicilia abnormis* and found to be effective.

Conclusions

The outer surface of the monuments provides ideal substrate for lichen growth leading to bio-deterioration. The growth of lichens even on modern buildings can make them unsightly, at least to

the architects. There are about 40 species known to colonise on Indian monuments. It is estimated that 40 species represent a small fraction of lichens discovered from the monuments studied from Orissa, Maharashtra and Karnataka alone. Studies on the monuments of Tamil Nadu yet to receive the attention of the concerned authorities including researchers. A detailed research on the above subject will provide vital information on the lichen diversity and its impact on monuments of Tamil Nadu. This research will also be useful in evaluating suitable eradication methods to conserve the monuments from further degradation.

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Microbial Deteriogens on the Sculptures at the Bandipur National Park

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Generally, art objects tend to deteriorate continuously due to physical, chemical and biological processes. Stone objects are also not an exception to this general order of the nature although they are misconstrued as sturdy ones. Broadly speaking, the decay in the stone objects owes to many physico-chemical and biological factors such as dampness, soluble salts, temperature variations, atmospheric pollution, biological activity. And consequently, the stone objects undergo change in colour, strength, coherence and dimensions.

Stone objects that are kept in the open-air tend to deteriorate in a relatively faster pace than those presented within a closed arena. For instance, the stone sculptures garden likely to undergo more deterioration than their counterparts that are presented in the galleries.

In this paper, it is attempted to present an account of the bio-deterioration that has been taking place on the stone sculptures that are on open-air presentation at the Bandipur National Park of Karnataka State in South India.

Stains of the Stone Sculptures at the Bandipur National Park

The Bandipur National Park is located within the Nilgiri Biosphere Reserve, which in turn lies in the juncture of Tamilnadu, Karnataka and Kerala. 17 stone sculptures (mostly of herostones and a few folk deities) and a rare Tamil inscribed stone slab-all dated back to 15th – 16th Century A.D. (that have

been collected from various interior pockets of the National Park arena of Bandipur, a small hamlet in the Channarayana district of the Karnataka State, by the authorities of the Bandipur National Park) are kept in open-air presentation in the foreground of the National Park.

Many of the stone sculptures that are in the open-air presentation here are seen overgrown with microbial growth of mosses, algae and lichen. Owing to the often-changing environment with sububious wind the stone sculptures at this area under study are subjected to constant danger of being wiped out forever. The secondary metabolites, which are acidic in nature, produced by the lichens covering the stone sculptures accelerate the bio-deterioration.

Lichens as Biodeteriogens of Bandipur Stone Sculptures

Of all the microbial bio-deteriogens, the lichens cause bio-deterioration constantly and continuously, due to the symbiotic co-existence of algae and fungi within them. While the algae (one of the co-partner microbes) disappear on scorching sun during summer the hyphae of the fungi (the other co-partner microbe of the lichens) that remain over the stone sculptures sprout again in the congenial environmental milieu that succeeds this vicious cycle effects constant and continuous bio-deterioration of the stone sculptures in open-air presentation at Bandipur National Park.

Limitations of the Present Study

1. The hypophytic bio-deteriogens, viz., mosses and liverworts in the area under study are not included in this present study owing to the availability of scanty data on this line.
2. Even the lichen specimens that have been studied were not subjected to taxonomic identification-although typological identification of them into foliose and crustose was done - due to the non-availability of taxonomists of specimens as well.

3. As the third type of lichens, namely, fruticose did not remain constantly over the body of the sculptures, their effects have been not studied in detail.
4. Foxing, the brown coloured rusty spots that appear over the stone sculptures were also not studied in this paper for the same reasons attributed in the earlier context.

Suggestion Proposed

As the secondary metabolites produced by the lichens are acidic in nature, the constant accretion of acidity over the stone surface of the sculptures reacts with the atmospheric chemicals resulting into formation of salts and this in turn effects disintegration of the stone sculptures in the long run. Hence, it is suggested that the stone sculptures at the Bandipur National Park need to be subjected to both curative and restorative measures of conservation. And this could be achieved by adopting the following two steps:

1. First, the microbial biodeteriogens at the area under study have to be collected and subjected to taxonomic identification.
2. Secondly, the authorities, concerned at the Bandipur National Park may be informed to adhere the measures of chemical conservation suggested to them by the conservation chemists and to prevent and protect the precious stone objects bearing the cultural and heritage values of Karnataka, in particular and India, in general.

Deterioration of Stonework and Methods of Restoration

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The deterioration in stone work is the result of various agencies acting on it. When stone work gets deteriorated, restoration should be done in order to bring them back to their original form.

Attack by Polluted Water

Rain water, made acidic by dissolved atmospheric gases such as oxides of carbon and sulphur have severe action on stonework, particularly sandstones and limestones. For example, sulphur compounds with moisture tend to dissolve limestones to give them a rough and weathered texture. When stonework is not frequently washed by rain but merely remains moist, a hard skin of calcium sulphate is formed which develops into surface blistering.

Attack by Soluble Salts

All types of soluble salts affect building stones in some way or another. The trouble starts with the migration of soluble salts by capillary action in the unprotected porous stone. Crystallisation takes place by evaporation of water from the surface and this sets up forces that can cause damage to the stonework. This damage is in the form of efflorescence, exfoliation and spalling.

Frost Action

The vulnerability of stones to frost action in temperate countries is related to the pore structure of the stone. Generally,

small-pored stones have a greater capillary effect so that large pored stones do not hold as much water as their small-pored counterparts. Much damage is caused to buildings as a result of frost following wet weather. The volume change is about 2% but is enough to generate expansive forces harmful to stonework.

Thermal Stress

During the day, the surface temperature of the stonework is warmer than its inner mass. At night, the condition is reversed. The stonework, therefore, is always subjected to a constant cycle of differential thermal stress between its surface and inner mass. Thus the stonework suffers fatigue, which leads to contour scaling and spalling.

Erosion

There is a tendency for soft stones to be eroded by strong winds. In coastal regions, erosion is accelerated by winds carrying sand grains.

Lichens, Moulds, Algae and Other Growth

Stonework, which is attacked by these growths contain unsightly stains, which are characteristically green, brown or black. These organisms thrive best in damp conditions, particularly outdoors. The strength of stonework is not affected but its appearance is marred.

Physical Action of Water

Humidity of different regions is one of the most important agencies harmful to stone. Building stones in monuments are porous materials and are characterised by a wide range of porosity up to 50%. Major portion of water, which penetrates into porous stone, comes from the outside environment during rain. Another way by which water penetrates is as rising damp by means of capillary absorption. The deterioration process takes place largely during the drying phase. Absorption, condensation and

evaporation are the processes by which physical action of water takes place

Absorption

The amount of water absorbed by a porous stone depends on the relative humidity of surrounding air and is called the hygroscopic moisture content. This is related to the partial pressure of the water vapour of air surrounding the body.

Condensation

When water vapour reaches the maximum concentration possible at a given temperature and it arrives on the surface where the temperature is equal to or lower than the dew point of the water vapour of the surrounding air, condensation occurs. Interstitial condensation occurs when the temperature of the surface facing the internal environment is above the dew point temperature. Also the relative humidity of air in the pores is higher than that of the external air close to the surface. Evaporation from the surface of a porous body is governed by external factors such as temperature, relative humidity of the atmosphere and the velocity of air flowing near the surface. The structure of the material affecting the movement of water to the surface also influences rate of evaporation.

Crystallisation of Soluble Salts

Water moving inside stone can contain a wide variety of substances, originating from the atmosphere, the soil or which contained in the original stone itself. Such substances crystallise as unsightly deposits on the surface of the stone, scientifically termed as 'efflorescence'. This occurs due to the low rate of ventilation, which causes an evaporation rate lower than the rate of replenishment of water by capillary migration from inside the wall. The salts are brought to the surface in solution during the wetting phase and most of the evaporation from the surface takes place during the drying phase forming salt crystals on the surface

If the surface evaporation takes place for a relatively short time, salts are deposited internally, which is termed as 'sub fluorescence'.

Air Pollutants

Oxides of carbon, sulphur, nitrogen etc., are pollutants, which deteriorate stone. These oxides absorbing moisture become acidic and dissolve the chemical constituents. Hydrogen fluoride is a strong acid, which affects both limestone and siliceous stone. It occurs near industrial areas. Hydrogen chloride is a strong acid, which transforms calcium carbonate into calcium chloride.

Stages of Stone Restoration

Diagnosis is the first step to carry out an in-depth study of the causes and mechanism of the decay process and the history of the object in need of restoration. Cleaning is the physical, chemical and mechanical removal of weathering crusts and deposits on the surface of the stones. Pre-consolidation means the superficial consolidation of stone and is applied before cleaning in case of advanced decay where direct cleaning may cause considerable irreversible loss of stone. Consolidation is the in-depth treatment of stone that has lost its cohesion to such a degree that its physical survival is imperiled. This consists of the impregnation of the weathered stone as well as a substantial part of the underlying sound layer of the stone. Surface protection is the application of a superficial film on unweathered stone, which acts as a barrier towards atmospheric pollutants and run water. Reconstitution involves the assembly of parts of old, consolidated stone by means of adhesives or even of substitute parts of new artificial stone. Maintenance by periodic inspection of stone monuments to assess the state of conservation and the efficiency of a particular treatment is important.

Repair Methods

Repair of stonework involves one or more of the following:

- ✦ Stitching of cracks caused by structural defects to be carried out after underpinning.
- ✦ Grouting of cracks not likely to worsen its structural condition.
- ✦ Repointing of mortar joints to improve appearance, reduce water penetration and unify the stones.
- ✦ Cutting and removing the defective stones and replacing them with compatible ones from similar sources as far as possible.
- ✦ All metal anchorages should be examined and the corroded ones to be replaced with bronze or stainless steel.
- ✦ Redressing of stonework when original surface has eroded.
- ✦ Creepers and other plants are to be removed by a weed killer that does not have adverse effect on the stone.

Cleaning Methods

For aesthetic reasons, the stone buildings need to be cleaned periodically, since the dirt may retain harmful substances and camouflage decay and structural defects. The choice of cleaning methods depends on the cost, speed and convenience to the occupants of the building.

Washing is a simple method involving washing away the accumulated dirt with a water spray and brush. This is a cheap and least harmful method but is also the slowest. This method is not effective in removing when dirt has stuck on to the stone for a long period.

Dry blasting is adopted under pressure to blow away the dirt. The grits of sand and flint are used for abrasive cleaning. This should be controllable.

Wet grit blasting employs a wet grit mixture for blasting. This is less harsh on the surface, but generates slurry, which is troublesome.

Mechanical cleaning involves abrading media such as carbonundum stone, grinding and polishing discs, rotary brushes etc. For ornamental works, hand tools such as chisels, stainless steel wire and small abrasive blocks are used.

Chemical cleaning is done with bases, which will evaporate along with a detergent.

Cleaning by laser is an expensive method requiring highly skilled application. The light energy (500 millijoules maximum) delivered by the laser beam is absorbed by the dark coloured staining on the surface and vapourised into plasma. The resulting shock wave removes the remainder of the stain by mechanical action. The very short duration of the laser pulse (60 nano seconds) prevents the heat from diffusing into the substrate. The firing frequency is controlled between 1 Hz and 60 Hz.

Preservatives

The preservatives that can be used for the maintenance of stonework should constitute a screen against atmospheric pollutants, dust etc. They should have a low thermal expansion and the physical and mechanical properties, which will allow them to adapt to the stone without damaging it. Alkoxy silanes, epoxy resins and waxes are applied as the main preservatives on stonework. However, the application of such preservatives requires skill in diluting and to make them cover the surface uniformly and also to penetrate into the stone.

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Conservation of Stone in India – Some Unsolved Issues

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Stone is one of the most important building materials. In early stages of civilisation, caves were hewn in rocks, and were used as dwellings, monasteries, temples, palaces and other purposes. Caves of Ajanta, Ellora, Kanheri and the Bagb are some of the famous examples. Quite often, these caves contained decorative elements like sculptures, carvings and wall paintings. In the second stage of civilisation, stone blocks or slabs were cut according to need were used for construction of buildings and sometimes for cladding as a veneer. Of this category there are thousands of examples. Stone was also used for making sculptures, tools of various types, utensils, etc. Such objects are also found in thousands in museums, palaces, *havelis* and residences.

With such an abundant use of stone, it is obvious that stone objects are available everywhere in plenty. Their deterioration is sometimes quite severe. Comparatively, stone is more durable than other types of materials, but it also has several limitations. The process of deterioration of stone depends on the nature of stone and on the deterioration and damaging factors to which it is subjected.

Nature of Stone

Stone is mostly heterogeneous in nature and is composed of different types of minerals and chemicals, with varying texture. For this reason, their basic properties, even within one type of stone differ considerably. Consequently, their durability and resistance to deterioration factors are not consistent. Broadly,

rocks are igneous, sedimentary and metamorphic. Within these main groups there are sub groups to define the properties of stone (Kumar, Anuradha, V., 2002).

By and large igneous rocks are more durable than the sedimentary rocks, or metamorphic stones. Sedimentary rocks, which are formed by the settlement of sediments, are more delicate. In comparison, the metamorphic rocks are stronger. However, there is such a large variation within one type, that any general statement is not of much consequence. It is therefore imperative that for a proper assessment of their deterioration process, the properties of different types of each stones are studied in detail.

Factors of Deterioration

There are various factors of deterioration, which can be categorised as

a) Chemical b) Physical and c) Biological

These are only broad headings and never affect the material in isolation. It is the combination of various factors, which is crucial. In the Indian context, our knowledge of deteriorating factors and their action is also very limited. Some institution should take it up as a serious programme of research to understand the fundamental nature of deterioration and its effect on Indian building stones. Needless to say, stone objects and buildings suffer from many problems. We can deal with many of the problems but still there is a large number, which remain unsolved. I shall mention here a few of them

Problems

Surface Erosion

Since a building is in the open and is exposed to sun and rain, its exterior surface gets eroded and quite often pitting is formed on it. It is necessary to assess the cause of erosion. In the absence of in-depth studies, wrong conclusion can be drawn. Having understood the cause of erosion, the next important issue is how

can the surface erosion of stone be stopped, or at least retarded. There are various types of coatings but as yet none of them is a perfect solution. Each one of them is having some deficiency or the other. In practical terms, it is not desirable to block the pores of a stone. Very often, it is more harmful than the erosion itself. We have yet to find a solution, which will consolidate the surface but will not stop the migration of water vapour from inside the stone, because otherwise it may cause eruption of the stone surface.



Sculpture Affected by Erosion

Effect of Sea Breeze

Sea breeze, which is always salt laden is extremely injurious to stone. On account of salts, the surface of the stone gets eroded and it becomes powdery (Lehmann, Janusz, 1970). The classic example is that of the Shore Temple, Mahabalipuram and the Sun Temple, Konark.

On account of salts contained in the air the stone also gets saturated with salts. It is not an easy job to extract the salts. Even if one succeeds in removing the salts, they again reappear because the source is perpetual. One has to



Sculpture Affected by Sea Breeze

find a solution to this important problem of salt laden air and avoid it.



Exfoliated Stone Surface

Exfoliation of Stone Layers

Quite often, we find that layers of stone, particularly of the sedimentary rock like sandstone separate out and split. Sedimentary rock, as we know, is composed of multi-layers. This type of damage can be seen at many places, for example in the spotted red stone of Mathura sculptures (Agrawal, O.P., 1973). In these sculptures, the layers of which the stone is composed are separating and in many a case have already fallen apart. The separation is on account

of the loss of the strength of binding material between the layers. In order to rectify the situation one should introduce fresh binder between the layers. First of all we are not sure which binder would last for a long time. We know that organic binders have a limited life. Apart from that when we introduce a chemical or a solution it does not penetrate deep inside. As such the binder binds the edges of the layers while from inside there is a void. As a part of a research project, we tried several methods at Mathura but none of them is satisfactory. More



Cracked Stone Sculpture

research is needed to find a solution.

Formation of Cracks

Very often cracks of various dimensions develop in the stone of all types. In the Taj Mahal marble, there are cracks all over the surface. We studied the phenomenon of cracks in the marble slabs of the Taj Mahal in great detail (Agrawal, O.P., *ix et al.* 1986). We came to the conclusion that the cracks had developed on account of various reasons, but mainly due to the weight of one slab over the other.

As a result of the change in the temperature there is shrinkage and expansion of the slab, and the result is the formation of cracks.

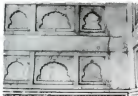
The problem is very acute and it can be stated as follows:

(i) To put it very mildly, we have no control on the various situations.

The building slabs are as they are, and we cannot change their weight or their position. Similarly, if there is a variation in the day and the night temperatures, we have no control on the climatic conditions.



Cracked Stone Surface



Cracked Marble in Taj Mahal

(g) Once the cracks are formed, we cannot fill any chemical or solution inside them. Very often there is no space for the chemical to go inside. On the other hand the rainwater may seep inside.

(ii) In some types of stone, for example in marble, there are inclusions of different materials like minerals (Pirsson, Louis, 1957). At these places, black or brown spots or mineral veins are formed. These spots or veins are the weak points in stone. But they are intrinsic part of the stone and cannot be changed.

Thus remains a problem to which one has to find a solution.

Control of Micro-organisms

In our country, with a tropical climate, having heavy rainfall and plenty of moisture, the growth and development of different types of microorganisms on stone is very natural. We can see presence of algae and moss over every type of building, including monuments and historical buildings. These microorganisms grow very quickly and cover the surface of the building. There are several



Temple Affected by Micro-organisms

techniques, including the use of ammonium hydroxide to clean the surface of the monument. We notice that during cleaning some amount of stone surface gets eroded. If the cleaning has to be done time and again, the loss could be very substantial. There are now biocides available, which can take care of the algae using a mild brush. Also there is no biocide known, which can prevent the growth of microorganisms for a long duration. As a result, once algae for example, are cleaned off, they again grow

very rapidly in 2-3 years time. They have to be cleaned off once again. Thus this cycle has to be repeated of and on (Agrawal, O.P., 1981).

The problem in respect of microorganisms is therefore two fold

(i) Development of a suitable cleaning agent, which would remove the microorganisms and clean the surface of the stone without much rubbing with a brush.

(ii) Development of a suitable biocide, which once applied on the surface of the stone would remain on the surface for a long duration, at least 15-20 years. It is not so very easy to clean the surface of the building every year, not only because of the danger to the stone but also because of the cost involved in a high building. Scaffolding has to be erected before one can think of cleaning the dome and other areas, which are at a height. It is not possible to erect a scaffolding every year or even every

alternate year. Needless to say the biocide must be of a type, which would not harm the stone in any manner.

High Rise Statues

In our country, there are many statues, which are quite high. Examples are the statue of *Balabala* at *Siravana Balabala*, statue of *Bhagwan Adinath* at *Banwar Gufa*, Statues of *Jain Parshwanath* in *Gopandol* in *Gwalior*. There also are a large number of monolithic decorative or inscribed pillars, for example the *Jain Manastambh* at *Kabon* in *Doria* District in U.P. There are a large number of *Asokan Pillars* also.



Monolithic Sculpture



Monolithic Carved Stone Surface

These statues and pillars suffer from almost the same type of damage and deterioration as found in the historic buildings.

However, the difference is that while the buildings have a broad base, the statues' bases are narrow. Apart from that, the sheer height of the statues is a problem. To reach the top of the statue scaffolding has to be erected, which would surround the statue on all the sides. Since some of the statues are free standing there is a danger of their toppling down.

Furthermore, many of the statues and pillars are under worship. As a result use of chemicals is sometimes not permitted on account of religious belief. One cannot ignore the religious sentiments for the sake of conservation. One has to find out such solutions, which would not be objectionable from the point of view of religion. This is therefore a special area, which needs our attention.

Water Repellency

Some types of stone, for example sandstone, are very porous and absorb a lot of moisture, which gives rise to several types of ills including the growth of microorganism. With the absorption of moisture, the action of salt is also increased. It would be a very desirable property, if the stone could be made water-repellent by the application of a or protective coating on the surface of the



Stone Pillar

stone. Even though, there are many chemicals, none of them is an ideal solution. There are several conditions, which must be fulfilled before a protective coating could be called ideal. Some of these are:

- 1- It should not change colour
2. It should not make the stone completely impervious to the exchange of moisture.
3. It should not form a crust on the surface.

The need therefore is to develop a protective coating, which would meet the requirements



Peruvu Sankshat Sculpture

Conclusions

We have mentioned some of the outstanding problems, which we meet in the conservation of stones, whether in buildings or in the museums. They can be solved only by concerted research, which must be not only in the laboratory but also in the field. Quite often, certain materials and chemicals succeed in the laboratory but fail in the field, because the conditions in the field are quite different to those simulated in the laboratory.

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Amaravati Sculptures and Their Problems of Preservation

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The Government Museum, Chennai is a multi-disciplinary museum established in 1851 with a total of about a thousand geological specimens. But today this museum is consisting of various collection sections like Anthropology, Archaeology, Art, Botany, Children's Museum, Chemical Conservation, Geology, Numismatics and Zoology and supporting sections such as Chemical Conservation, Design and Display and Education Sections.

Introduction to the Amaravati Gallery

The Amaravati sculptures are the *Pierre de resistance* of the Chennai Government Museum on account of their artistic masterliness and historical



Model of Amaravati Stupa

significance. They are dated to a period spread over five centuries from 2nd Century BC to 3rd Century AD. They are parts of a huge Buddhist stupa that had been constructed over this period

of time, and so their artistic style varies from part to part. "The *stupa* is stated to have been well looked after for some centuries, after which it fell into neglect. So serious was the neglect that all awareness of the *stupa*'s significance was lost and the local people are said to have used parts of the limestone slabs, which fell off the main structure for preparing shikar lime. It was in this state of ruin and neglect that Colonel Mackenzie, then Surveyor General, discovered them in 1801 in a trench 10 feet wide and 12 feet deep near the village of *Amaravati* or *Amaravati*, on the banks of the river Krishna, 45 miles west of *Vijayawada*. He is stated to have recognised the value of the slabs, made some excavation on the spot and in 1815 published an account of his proceedings. In 1830, Mr. Robertson, Collector of Masulipatam, brought some of the *Amaravati* sculptures to Robertsonpet near Masulipatam named after him. He kept them in the marketplace for beautifying it. In 1835, Sir Frederick Adam, Governor of Madras visited



Enlaided Limestone Sculptures

Robertsonpet and saw the sculptures and ordered the same to be brought to Madras kept with the Madras Literary Society. After Surgeon Balfour took over as Officer-in-charge of the Madras Museum, he made efforts to serve them for the Museum. As a result, the first batch of sculptures arrived in 1856. Most of them were sent to London in 1859 and now they are in the British Museum at London where they form now one of its fine galleries.

Batches of these sculptures continued to come from *Amaravati* as more and more digging was done. One was a group of sculptures sent by Sir Walter Elliot in 1865, which were also sent to London after lying neglected in the fort for sometime. There were still several sculptures lying in neglect in the museum and in Mr. Alexander's house at *Musalpattam*. It is these that Bache collected in 1877, brought them to the Madras Museum and put them on display.

Dr. Bache displayed them in a gallery, long and broad. The slabs were quite heavy and he thought it best to embed them in walls or place them on raised brick supports. He also built a single wall of Portland cement to simulate a part of the structure of the *stupa* by embedding slabs in what might have been their original position on the *stupa* wall. At one part in the gallery, there is a trench below ground level where also the slabs were embedded.

Condition of the *Amaravati* Lime-stone Sculptures

The *Amaravati* sculptures are prone to salt action and deterioration by atmospheric pollutants. The moisture present in the air dissolves the acidic vapours and gasses and the acids thus formed adhere to the surface of the lime stone sculptures and make the sculptures to disintegrate. The surface of the limestone sculptures takes very easily the ugly looking oily accretions because of the human touch. The salt absorbed by the limestone sculptures is removed by poulticing using moist and neutral paper pulp applied to the surface of the sculpture. In the case of the affected loose sculptures, after all the salt present is removed by immersion in



Affected Limestone Sculpture

distilled water a preservative coating of 2% solution of poly vinyl acetate in acetone was applied. Since these sculptures are embedded on to the brick lime constructed walls of the gallery, they showed further crystallisation of salts. In 1989-90, the Government of Tamil Nadu sanctioned a sum of Rs. 8,00,000 for the new *Amaravati* Gallery along with air-conditioning the gallery. Since there was some delay in the execution of work, the project was given up. In 1994, the first author studied the problem of conservation of the *Amaravati* limestone sculptures in the Government Museum at the British Museum. Both the authors prepared a project report for the establishment of a Buddhist Centre in the Government Museum, Chennai in the model of the *stupa* and financial assistance was expected from the Government of Japan. After persistent requests, the Secretary to Government, Department of Culture set up a Committee comprising Dr. Tej Singh of the National Research Laboratory for Conservation of Cultural Property, Lucknow and Dr. R. K. Sharma, Director (Science) of the Archaeological Survey of India, Dehradun to study the problem of the *Amaravati* Sculptures in the Government Museum and to suggest the restoration measures with the help of the authors of the paper, Dr. R. Nagaswamy, Former Director of Archaeology, Dr. B. Narasimash, Former Superintending Archaeologist, Archaeological Survey of India, Chennai Circle etc. The report of the committee was sent to the Government asking financial assistance for the establishment of the New *Amaravati* Gallery. The report specifically requested for the removal of the embedded sculptures from the walls of the gallery, conserving them, redisplaying in the properly designed gallery with all modern display equipments for increasing the life of the *Amaravati* limestone objects. There was no reply from the Government of India but the Government of TamilNadu provided a token sanction for the removal of the sculptures from the walls of the gallery. Since the Nehru Trust for the Indian Collections at the Victoria and Albert Museum was interested in arranging the experts from London, an International Seminar on

Conservation of Stone Objects with Special Reference to the Limestone Objects was arranged in the Government Museum, Chennai in collaboration with the Indian Association for the Study of Conservation of Cultural Property, New Delhi and the Nehru Trust for the Indian Collections at the Victoria and Albert Museum, London of New Delhi in December 2001. The International Seminar on Conservation of Stone Objects will be useful to formulate the strategy for conservation of the *Amaravati* limestone sculptures in the museum. Both the authors have visited the *Amaravati* limestone sculptures in the British Museum, London and their knowledge in this will be made use of in the conservation and display of the *Amaravati* limestone sculptures in the museum.

Removal of Sculptures from the Wall

Since the removal of the limestone objects from the wall was the most sought after suggestion, it was decided in the beginning to remove the affected limestone sculptures from the wall of the gallery. As such 134 sculptures have been identified for removal by the use of power tools with the help of the Archaeology Department, Government of Tamil Nadu.



Limestone Sculpture Before Removal

Proposed Conservation Treatment

The limestone sculptures are found with dissolved salts as they are found embedded on to the walls. The ingress of water carrying dissolved salts are the main reasons for the salt action, it has been decided to remove the salt by dissolution and or by poulticing with neutral paper pulp with distilled water. 134 sculptures have been identified to be removed from the wall. After their removal, the cavities in the walls will be filled with



View of the Sculpted out Wall After the Removal of the Sculptures

similar lime mortar to match the environment. All conservation measures will be taken to redisplay them in the proposed New Amarnath Gallery in the museum.

Conclusions

Amarnath limestone sculptures in the Government Museum, Chennai are the rarest collection of the country and all possible measures to conserve them will be taken as

soon as we get best information from the conservators who have participated in the International Seminar on Conservation of Stone Objects with Special Reference to Limestone Objects. We hope to save the deteriorating Amarnath limestone treasures of the museum for posterity.

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Amaravati Sculptures and Their Problems of Preservation

- V. Jeyaraj & R. Balasubramanian



Mr. R. Balasubramanian Explains the Problems of the Limestone Sculptures in the Gallery



Embedded Limestone Sculpture Affected by Salt Action



Embedded Limestone Sculpture after Removal of the Salt



The Wall is being Marked for Scraping the Wall



The Appearance of the Wall after the Removal of the Limestone Sculpture

Amaravati Sculptures and Their Problems of Preservation

A. T. Jayaraj & R. Balasubramanian



Backside Sculpture before Removal From the Wall



The Wall is being Scooped-out for Removing a Limestone Sculpture



Limestone Sculpture after Scooping-out the Wall



Side View of the Sculpture with Scooped-out Wall



Backside View of the Limestone Sculpture

Preservation of Stone Objects in the Government Museum, Vellore

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Cultural objects help to trace history and culture of a country or a race. Therefore, it is the duty of Curators to preserve the artifacts of bygone days for posterity. Our forefathers carefully carved sculptures, constructed religious and secular monuments and installed carvings. Many images carved out of stone were erected and worshipped. Further, our ancestors left for us paintings, woodcarvings, coins, metal objects, bronze icons and weapons.

Stone sculptures, architectures, epigraphs of earlier ages bear witness for culture and history of contemporary rulers and people. Therefore, new findings, excavations of art objects and epigraphs change the history of the dynasties and kings. Further new cultural facts come to light. In some findings similar cultural objects are unearthed in distant places. Ornaments and weapons have similar pattern even though found in different countries reigned by different dynasties and kings. They show that they had cultural contacts and trade links among different dynasties of the contemporary world. This paper deals with preservation of stone objects in the Government Museum, Vellore.

Stone Sculptures

This museum has a very good collection of granite stone sculptures collected from both Vellore and Tiruvannamalai districts. *Shilpa* carved and chiseled sculptures out of granite with the patronage of kings, traders and local people. Religion was the main thrust to produce sculptures and construct religious

edifiers. Due to some reason or other those structures were damaged, mutilated and blurred. Hence it is our duty to restore these art treasures for posterity.

The collection of stone objects to this museum is interesting. The majority of the collection in this museum was the contribution of Dr. V. Jeyaraj and myself through field collection and as treasure-trove finds. Most of the best collections of stone sculptures are displayed in the museum itself and objects like pillars, hero-stones etc., are displayed in the Sculpture Garden of this museum. I acquired some



*Restored Hero-stone, Sri Gostery
A.D. Vannan, Palar Taluk
Tiruvannamalai District*

architectural parts of an early Chola temple of *Manikankavara* from Tirumalpur, Arakkonam taluk to the Government Museum, Vellore. Among a number of pillars two of these structural parts were found to be the broken pieces of a stone pillar. But shape of the broken faces gave clue that they might be the parts of a pillar. Dr. V. Jeyaraj, then Curator of the museum and the present Curator of the Chemical Conservation and Research Laboratory of the Government Museum, Chennai had restored two hero stones, which were acquired by him during his tenure as Curator in this museum. They are the hero stones from *Vannan* and a hero stone from *Marupate*, Vaniyambadi taluk. In the broken faces of the pillar, small holes were made and inserted a steel rod to hold other broken part above it. The steel rod was fixed with the help of a synthetic resin. This method of doweling joined two broken parts to erect as a single pillar. Originality was maintained and the details of the pillar were found as a whole. Some type of stone pillars were used in *Siva* temple at *Kattumannarkudi* during the early Chola period.

Conservation Treatment

Curator's job is to collect, document, preserve, present, do research on the objects etc. The Department of Museums, Government of Tamil Nadu is aiming at making its Curators to have the knowledge of conserving the objects also. Two of the stone sculptures on acquisition were found smeared with tar. One hero stone of artistic wealth, depicting a hero and his spouse was spoiled due to tar. Kerosene soaked cotton was left over the affected areas for three to four hours to soften the smeared tar. The area was brushed with nylon brush. This treatment was repeated until tar was removed from the hero stone.

A *sanku* stone sculpture was also found to have been smeared with tar before its acquisition. Cleaning with kerosene and nylon brush was carried out to remove the smeared tar. This museum besides preserving all types of objects, conserves and restores stone art object too in order to make them to have their original artistic features.

Conclusions

All types of preventive conservation is carried out in the museum itself by the Curator and the technical staff of this museum. If any problematic case is found, then the help of the Chemical Conservation and Research Laboratory is sought. Besides these, Conservation training programmes were arranged in the past for the staff as well as to those interested in the museum.

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Conservation of Museum Objects of Stone

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Stone is one of the most durable of building materials and has been used in the construction of monuments and carving of sculptures from times immemorial. Even such a material, however, is not completely immune to the effects of environment and other decay-causing factors. The physical and chemical alterations taking place in stone exposed to the weather and the process of slow deterioration resulting over long periods of time is aptly termed as weathering. Rapid deterioration is also possible, when stone is subjected to certain conditions. Physical erosion caused by sand-laden winds and constant impact of rain water, the deleterious effects of salt spray on monuments on the sea-shore, the damage caused by acid rain on urban structures and the effects of soluble salts present in the stone are some of the examples of deterioration that can take place in a comparatively short time.

Conservation of stone monuments and objects consists in (i) identifying and eliminating the sources of deterioration (ii) reversing as far as possible the adverse alterations that have taken place due to the above factors and (iii) taking measures for preventing future deterioration as far as possible.

From the conservation point of view, a stone object kept in the sheltered conditions of a museum is evidently much better placed than a monument or sculpture exposed to the elements. Stone objects preserved in museums, however, are often originally from monuments and excavated sites and it is possible that some of them might have acquired deterioration-causing factors from their

original location. It is necessary, therefore, to examine the condition of each object and take suitable conservation measures before putting it on display in the gallery or keeping it in storage, as the case may be.

Conservation Problems of Stone Objects in Museums

1. Surface Deposits

When a stone object is first brought into a museum, it is more often than not found to be covered with a deposit or incrustation. This could be soil if the object is recently recovered from an excavation. The deposit could be just dust and dirt if the sculpture or object was rather kept in uncontrolled conditions. If the sculpture was earlier in a temple, it is likely to be covered with patches of oily matter. The practice of whitewashing entire surfaces of walls and even sculptures, as a part of temple renovation, is in vogue in some places. The temple sculptures could therefore be covered with lime-wash. Similarly patches of oil paints or other types of paint are sometimes found on sculptures through inadvertent contact.

2. Stains

Stains could form on stone surfaces due to prolonged contact with extraneous matter in the presence of moisture. The risk is greater in the case of sedimentary rocks like sandstone, limestone (including marble) etc., because of their porous structure, making their complete removal almost impossible.

3. Soluble Salts

When a stone object is buried under ground, it can absorb soluble salts like sulphates, nitrates and chlorides from the soil. When the object is recovered after excavation and exposed to the atmosphere, the salt solutions within the pores of the rock migrate towards the surface during evaporation and after the water has evaporated, form a whitish salt incrustation on the stone surface, damaging the surface of the rock.

In wet weather, the salt can re-dissolve and re-enter the pores and with the next advent of dry weather, re-crystallise due to evaporation either within the pores or on the surface. This process can continue with changing weather cycles and due to the repeated dissolution and re-crystallisation of the salts within the pores of the rock, the pores are subjected to tremendous strain because the formation of salt crystal from the solution involves appreciable increase in volume. In practice, rocks suffering from salt action have been found to become extremely friable, even being reduced to powdery condition in extreme cases. Soluble salts can pass from the soil into the foundation rocks of monuments through capillary action and migrate gradually upwards. Salts present in the atmosphere can deposit themselves on the stone surface and seep inwards.

In the case of museum objects, soluble salts may be already present within the object when it is brought to the museum. Cases have also been recorded of stone objects in museums absorbing soluble salts from masonry pedestals or walls on which they have been mounted.

It may be noticed in this connection that salts that are not soluble in water, when present in the rock are not harmful because they cannot get into solution and therefore cannot react with the rock either chemically or physically through crystallisation.

Conservation Methods

1. Cleaning

Cleaning of stone sculptures is necessary both for aesthetic reasons and for protecting the stone from any harmful effects that the deposits or incrustations may be having on the surface through chemical or physical reaction. Choice of the cleaning agent has to be done with care. It has to be safe besides being effective. At the end of the cleaning, all traces of the chemicals have to be removed by thorough rinsing with soft water.

(a) Dust and Dirt

For the removal of dust and dirt, dry brushing with a soft brush is first done to remove as much of the loosely adhering deposit as possible. Then a 1% solution of a non-toxic detergent is applied followed by brushing and rinsing with water. The process is repeated, if necessary until the cleaning is complete. If the surface is also greasy, a few drops of liquor ammonia are added to the detergent solution. If the dirt is strongly adhering, a warm solution of 40–50°C may help.

(b) Oily Matter

Patches of oily matter on the stone surface can be removed with the help of organic solvents like dichloro-ethylene or carbon tetrachloride. Great care has to be exercised in the uses of such solvents since their fumes are toxic. Old and hardened oily incrustations may need stronger methods. A warm 5% solution of washing soda (sodium carbonate) has been found to be useful. In more difficult cases, a 2% solution of caustic soda (sodium hydroxide) may have to be used. Since this is a strong alkali, much caution is required in its use. Gloves may be used to avoid physical contact. In all cases, brushing and thorough rinsing with water is necessary. Repeated rinsing for the removal of all traces of the chemicals is needed when strongly reactive reagents like caustic soda are used.

(c) Paint

For removal of oil paint streaks and patches, solvents like isopropyl alcohol, cellosolve, acetone, amyl acetate, either individually or in mixture, may be used. When a slightly stronger method is called for, amines like butyl amine or triethylamine or a 5% solution of ammonia may be useful. For removal of very old and tough paint coatings, a 5% solution of caustic soda may have to be used, observing the usual precautions.

(d) Whitewash

Removal of limewash coatings from stone sculpture is rather laborious and time-consuming, especially when the surface is rough and the coating is firmly adhered.

Since lime is alkaline, the cleaning solution needs to be acidic in nature. Strong mineral acids like hydrochloric and sulphuric acids, though likely to be very effective, are not advised because if some traces of the acids remain in the stone at the end of the cleaning, they will react with the minerals and cause deterioration. The chloride ion is particularly active and mobile and has to be strictly guarded against.

To begin with, as much of the coating as can be removed physically by careful chipping off, is removed by this method. A 5% solution of acetic acid is applied on the remaining coating and allowed to react for 12-15 minutes. The slightly softened coating is now brushed off, using hard nylon brushes. Tooth brushes may be used for minutely carved areas. Under no circumstances should wire brushes be employed, since they are likely to scratch the stone surface. The cleaning is finished by a thorough rinsing with water.

(e) Special Methods

Cleaning of Marble

Marble can easily acquire stains because of its fine-grained structure and its light colour sets off the marks or stains prominently. Great care is needed in the cleaning of marble since the glossy surface has also to be preserved.

A dilute solution of a non-ionic detergent like Teepol is used for general cleaning. A few drops of ammonia may be added when the surface is greasy. Since ammonia volatilises and will not remain on the surface, it can be safely used.

Spirite is a clayey material used to clean marbles.

The chemical composition of Sepiolite is magnesium silicate and it is greyish in colour. A paste of the required consistency is prepared by mixing it with distilled water.

(i) Removal of Stains

In marble and limestone sculptures, removal of stains is a rather ticklish problem. Stains are usually caused due to prolonged contact with the soil and often contain iron oxides derived from the same and hence the stains are usually reddish brown in colour.

A suggested method is to apply EDTA (ethylene diamine tetra acetic acid) in the form of a paste made with carboxy methyl cellulose. The paste has to remain in close contact with the stain for a few hours. If necessary, a second or even third application can be made. As much of the stain as possible may be removed and the rest may be camouflaged with chalk powder or some other suitable material. For removal of persistent greyish stains left by moss growth or strongly cemented dirt etc., a 5% solution of sodium bicarbonate is found to be effective.

2. Extraction of Soluble Salts

The highly deleterious effects of soluble salts like chlorides sulphates and nitrates present in the stone have been described above. Of these, chlorides are particularly harmful for reasons also mentioned above. When these salts are present in a stone object, it is necessary to remove them completely.

Neutral paper pulp mixed with distilled water is applied.

What happens in this process is that first, the distilled water will pass into the pores of the rock, dissolving the salts present. Next, during evaporation, the salt solution will migrate to the surface and be absorbed by the paper pulp. If the process is sufficiently repeated, the salts are completely extracted. At the end of this treatment, the surface of the sculptures, rendered friable earlier by the salt action, was consolidated and strengthened (by methods

to be described in the next section). The sculptures were finally remounted on wooden pedestals in the gallery.

3. Consolidation and Strengthening

It may sometimes happen that a stone object, received in a museum, might have lost its strength and cohesiveness due to reasons such as salt action, leaching of soluble minerals through prolonged contact with moisture etc. Sustainable steps for consolidating and strengthening such an object will be necessary so as to avoid damage.

The choice of the consolidant to be used for this purpose is crucial. Epoxy resins have several good properties (such as strength, chemical stability, ease of application, absence of dimensional changes after setting etc.) to recommend them. The only point against their use is that once they set, it will be practically impossible to remove them with solvents and this militates against the principle of reversibility, which is a highly desirable parameter in any conservation procedure. Polymethyl methacrylate has been found to be suitable. It has the requisite strength, while remaining soluble even after a long time. It is perfectly colourless and transparent and does not alter the appearance of the stone in any way.

(a) Polymethyl Methacrylate

A 5-10% solution of polymethyl methacrylate (PMMA) in solvent is used. For consolidation of small objects, the technique of vacuum impregnation may be used. In this, the consolidant penetrates deep into the object and achieves the strengthening of the entire object. The object is placed in the PMMA solution in a beaker placed inside a desiccator. The air inside the desiccator is evacuated with the help of a vacuum pump. After about half an hour, the object is taken out and dried at room temperature. The above method is not practicable for large objects. In this case, the solution is applied on the surface with a brush, aiming to achieve as much penetration in to the object as possible, which

is facilitated by keeping the stone surface warm with the help of infrared lamps, before each application. Four to five such applications may be made.

(b) Ethyl Silicate

For siliceous rocks like sandstone, ethyl silicate has been used successfully for surface consolidation. Ethyl silicate mixed with water is applied on the affected surface. Ethyl silicate undergoes hydrolysis, releasing minute silica particles that fill the gaps in the friable surface and consolidate it. This is also an irreversible process but since the consolidating material is the same as the original constituent of the rock, the method is considered permissible.

(c) Limewater

Friable surfaces of limestone objects can be similarly consolidated by repeated application of limewater. The lime is gradually converted to limestone due to reaction with atmospheric carbon dioxide, resulting in the strengthening of the surface.

4. Repairs

For repairs of stone objects, epoxy resins have been found to be very effective. They are available under the trade name of Araldite marketed by CIBA GG, in different grades. The required grade has to be selected for the particular use we have in mind. The resin can fill minute cracks directly. A mixture of stone powders (the same variety as the object) and the resin may be used for filling wider cracks and gaps. For joining parts of stone sculpture, dowelling has to be used. Repairs carried out with the help of epoxy resins have been found to be almost permanent.

5. Application of Preservative

While it is now an accepted procedure to preserve stone monuments and outdoor sculptures by the application of preservative coatings, the question may arise whether such a coating is necessary for objects kept in a museum. When we

consider the present levels of atmospheric pollution in urban environments, particularly the level of sulphur dioxide and oxides of nitrogen, it may be concluded that it will be safe to protect museum objects also with a preservative coat.

The coating has to be chemically stable, should be colourless and perfectly transparent and should not react with the rock surface in any way. It should form a tough and elastic film. Above all, it should remain soluble even with the passage of considerable time so that we should be able to remove it with solvents at any time it deem necessary. Polymethyl methacrylate (PMMA) satisfies all these conditions. A 1-2% solution in toluene may be applied with brush or by spraying. A mask has to be used while spraying. The preservative coating enhances the appearance of the sculpture, besides protecting it from the atmosphere. There is the additional advantage that any future deposition of dust etc., will be on the coating and not directly on the stone surface. Future cleaning therefore will involve just the removal of the coating with a toluene / acetone mixture, followed by the application of a fresh coating.

Problems of Conservation of Stone Monuments

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The weathering of stone is a common problem to all building materials. With the advancement of science, modification has become necessary for devising ways and means to preserve our cultural heritage. No stone is permanent to withstand the onslaught of atmospheric changes indefinitely as well as other deteriorating agents due to changes in the ambient conditions and the cycle of changes occurring so rapidly.

The stones used as building materials generally are of a variety of composition and in geological language may have been derived from (i) Igneous rocks (ii) Sedimentary rocks and (iii) Metamorphic rocks.

Igneous Rocks

These rocks are formed by cooling and solidification of molten rock i.e. magma. These are very hard, non-porous and very stable. These are divided as acidic, basic and intermediate rocks based on the percentage of silica in the rock.

Name	Types of Rock	Content of Silica (%)
Granite	Acid rock	66-75%
Diorite	Intermediate	52-66%
Basalt	Basic	45-52%

The above terminology is actually based from the fact that silica makes acid solution with water whereas alumina is amphoteric i.e. neither acidic nor basic. The other oxides are bases.

Sedimentary Rocks

Any rock exposed to surface undergoes disintegration through physical, chemical and biological processes-what we call it as weathering. The tiny particles of these disintegrated rocks are being transported by water, wind and by movement of ice. When these transporting medium is unable to carry load, the mineral grains are deposited either on ground or under the sea and slowly sediments by layer by layer, which in turn forms sedimentary rocks. e.g. sandstone, limestone and shale, which are porous in nature.



Shore Temple From Western Side, Mahabalipuram

Metamorphic Rocks

These are formed due to physical and chemical changes undergone by the rock through the influence of heat and pressure or both. Thus, granite becomes gneiss, sandstone to quartzite and limestone to marble. The type of rock of some important Indian monuments have been examined petrologically by Archaeological Chemists and classified as follows.

Shore Temple, Mahabalipuram	— Granite/Granite gneiss/porphytic granite
Kailasanatha Temple, Kanchipuram	— Brownish sandstone
Brihadeswara Temple, Thanjavur	— Granite gneiss
Gometeswara Statue, Sravanabelagola	— Biotite granite
Thousand Pillared Temple, Hanamkonda	— Dolomite
Sun Temple, Konarak	— Khondolite
Thaj Mahal, Agra	— Marble
Khapuraho Group of Monuments	— Sandstone
Red Fort, Delhi	— Red sandstone

It is necessary to find out the chemical changes, which have occurred due to reaction of chemical ingredients present in the stone and combining with other atmospheric materials have changed themselves resulting in weathering of stones. Thus, the work involves is a massive one and will be the combined efforts of a group of dedicated workers in various disciplines like micro-biologist to identify the presence of micro-biological agents on stone, petrologist to study the rocks through thin sections, geologist to study the stone materials for rock formation takes place with time and physicist to use the properties of materials under study with instruments. Thus, the whole process becomes a geo-chemico-petrological phenomenon involving multi-disciplinary and inter-disciplinary approach. The study of the climate, the location of monument, ambient air quality, humidity and temperature evolution followed by chemical analytical data to assess the extent of damage to a stone with time forms the basis. The secondary part then comes is the treatment, consolidation, anti-biological treatment and finally the preservation.

The disintegration of the stone monuments and stone objects may be due to the various factors as follows:

1. Micro-biological factors
2. Inherent weakness of stone fabric
3. Deterioration due to physical weathering, air, sand, pollution, humidity, temperature etc. and
4. Chemical weathering.

Microbiological Factors

This is the most dominant form as the monuments are lying in the open. The microbiological agents in the form of bacophytes, algae and pteromphytes etc., are found on the surface of the stone and causes the biochemical decay or alteration of mineral grains. Since, their nature is to grow, they penetrate the pores of the stone fabric, produce either in cracking or weathering of the stone and act chemically and mechanically. The stone monuments thus become patchy and ugly with the formation of green and black colour. Much research has been done by various scientists to determine the effects of nitrifying and sulphur forming bacteria. The ultimate end product is acid in each case, which in turn decays the stone.

Inherent Weakness of Stone Fabric

At the time of formation of rock, various factors like physical, chemical and mechanical are involved, which produce non-homogenous material and also not having uniform mechanical strength all over. These are due to weak spots produced in the stone, which is known only after stone is exposed to the atmospheric conditions. One of them is the rock of Sedimentary nature and having different structural composition. The second and much noted one is the presence of shakes and vents, which are called micro-cracks in the stones. Since the ingredients of the stone materials are of different chemical mineral as well as of composition, the co-efficient of

contraction and expansion also vary resulting in the formation of bigger cracks.

Deterioration Due to Air, Sand, Pollution and Other Relative Factors Like Humidity, Temperature etc

Air pollution is one of the most important agencies, which causes the decay of many monuments by way of producing oxides of nitrogen, particulate matters, acidic rains and metallic fumes due to industrial developments. The action of wind has its own devastating source resulting in the erosion caused to different monuments. The air contains a large number of solid particles of silica, resinous materials, metallic particles and allied matters. When the wind speed is much it strikes the surface of the monuments producing erosion by mechanical action as it happens in case of monuments in Mahabalipuram, Konarak etc. The monuments located at seashore are affected by saline winds. Granites are particularly susceptible to mineral disintegration due to co-efficient of expansion and contraction on account of difference in temperature than sandstone.

The salts have their own deteriorating effect. The soluble salts in solution get in to the pores of the stones while sand grains abrade the surface. The physical weathering of stones takes place due to various factors like wind, rain, solar radiation and the cumulative effect of all these. Due to high humidity, the soluble salts go into solution and penetrates the pores of the stones but when the humidity is less and more evaporation takes place, the soluble salts come out on the surface causing damage to the stone.

Chemical Weathering

Chemical weathering is due to the reaction of the materials of which the monuments are made and the constituents present in the atmosphere. Chemical decay is associated primarily with materials, which are having calcium carbonates and decay in non-calcareous materials may result due to absorption of the decomposition products of calcareous materials.

In the air, the principal decaying agents are oxides of carbon, sulphur and nitrogen. In damp leaching of soluble materials, oxygenated and carbonated water are the main factors for deterioration. Soda and potash are released by hydrolysis of feldspar and go into as carbonates, which are potent source for dissolving the silicate rocks. In tropical condition, hydrolysis, oxidation and carbonation produce residual products of diversified nature. Complex aluminosilicates are decomposed with the formation of kaolin. In case of further decay, the above reaction does not stop at hydrated aluminium silicates but continues further with elimination of silica and accumulation of hydrated oxides of iron, manganese and aluminium. e.g. Shree temple, Mahabalipuram is made of granite rock, which is coarse-grained. Mineral alteration has taken place. Kaolinisation of feldspar, limonitisation on iron and chloritisation of biotite are some of the important occurrences. Salt laden winds further aggravate the situation.

Stone are more susceptible to deterioration physically than limestone in humid atmosphere. Schists are broken down by mechanical action. Basalts are to be the most resistant to carbonated water. Quartz are also most resistant.

Since we have made tremendous progress in conservation techniques, which go a long way in arresting these process of decay – chemical disintegration, physical disturbance, gravity factors, mineralogical and petrological alterations, biological and entomological decay, disintegration can be slowed down and perhaps be stopped, if preventive and curative measures can be taken in time.

Conservation

The main objective behind the conservation is to keep the stone monuments in a good state of preservation for posterity and to reduce the rate and incidence of decay in addition to the chances

of disintegration and disfigurement. Generally the conservation of stone implies the following:

1. Cleaning,
2. Consolidation and
3. Preservation.

Cleaning

Cleaning of monuments involve the use of different chemicals, which are inert to stone matrix but react at the surface to remove the unwanted resultant materials due to minerals alterations or deposits due to air pollutants, causing more damage to the underlying stone matrix. In addition to this, there are harmful effects such as soluble salts, soot, particulate matters, vegetation and microbiological growth. Our main aim is to relieve the stone with the above without damaging



*Exterior South Wall of the Shree Temple,
Mahabalipuram Being Protected by Paper Pulp*

Treatment with water and a surface detergent followed by selective techniques of preservation is the usual trend in cleaning. Paper pulp and absorbent clay-packs have given the best result. *Sepiolite* and *attapulgite* having similar composition and rectangular structure have been used for removal of encrustation and other unwanted materials. These clays are mixed with solvents and applied in packs on the surface to be cleaned. This method is very useful in case of greasy and waxy surfaces. For soluble salts, water based packs are used. Techniques, which produce harmful effects and also injurious are to be avoided. Mechanical method, which produces superficial temperature change, may not be used at all. Water mist technique and urea glycerin – Bio-pack method can be used for cleaning of marble.

Consolidation

Consolidation is the second part of the process, which increases the cohesive strength, improves upon the mechanical characteristics and leads to adherence of altered layer. Porous materials are very well consolidated due to in depth penetration. However, viscosity of the consolidant has to be adjusted so that maximum cohesion could be achieved or formation of scum would take place leading to dangerous results.

Both organic and inorganic materials are used as consolidants and they have their own advantages and disadvantages. Inorganic materials are more durable than organic one but they are non-elastic. However, organic ones are better suited in improving the treated stones resistance to mechanical stress. Some of the good consolidants are ethyl silicate, acrylic resins, silicates and vinyl resins.

Preservation

When the above-mentioned two steps are complete, the preservation i.e., protection against climatic condition comes in or otherwise problems would arise. If it is strangled to use the same protective coating as consolidant, it should be done to reduce the source of environmental deterioration and to provide surface protection. A large number of coatings are now available but care has to be taken to use only those, which have been tried and tested in different climatic conditions. Generally a coating with fungicide is used before giving a final coat of preservative on the stone surface. Zinc silico fluoride or sodium penta chlorophenate are often used as fungicides on stone monuments. Poly methyl methacrylate is one of the acrylates, which is generally used as preservative coating. In recent times, use of double components like potassium methyl silicate plus PMMA in toluene has become very successful on stone monuments.

The Scientific Investigation and Preventive Conservation of the Amaravati Sculptures in the British Museum

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The site of the Great Stupa of Amaravati was excavated between 1797 and 1909. Sculptures from the excavation undertaken in 1845 by Sir Walter Elliot were taken first to Madras and then to London and the British Museum. Sculptures from the site are also to be found in the Government Museum in Chennai and in other museums. The sculptures are exceptionally fine examples of Indian carving, with a large amount of details. They are carved in a green tinged, partially metamorphosed limestone, commonly known as 'Palnad marble', which was imported to the site of the stupa.

In 1868, a large format photographic record and dialogue on the sculptures¹, 'Tree and Serpent Worship', was published by James Fergusson. The photographs show that the sculptures were not in perfect condition, but that many of them exhibited less signs of deterioration than were apparent in the middle of the 20th Century. In the interim surface flaking and powdering, and on some sculptures the loss of a whole face parallel to the carved surface had occurred. The pattern of loss was observed to be the same on sculptures in the collection of the British Museum and in the collection of the Government Museum, Chennai.

In 1960-61, the Government Chemist of the Archaeological Survey of India and the Keeper of the Department of Research Laboratory in the British Museum, undertook investigations into

the cause of the deterioration of the sculptures. The chemistry of the stone and the prevailing environmental conditions at the site of the *rapas* at *Amaravati*, Madras and London were considered. The investigations indicated that the higher relative humidity in Madras and London were the likely cause of the deterioration. In 1972, analysis of a small group of the sculptures in the British Museum suggested that sulphation of surfaces had occurred and that this, combined with a large acid insoluble component in the stone was responsible for the deterioration.

In 1983, British Museum scientists carried out a fuller investigation of the chemistry and geology of the stone from which the sculptures were carved. This study was carried out as a co-operation between the Department of Conservation and the Department of Research Laboratory, now the Department of Scientific Research. This study resulted in a much fuller understanding of the major deterioration mechanism of the stone. In particular the investigation supported the view that the correct method for preventing deterioration of the sculptures was to keep them in a controlled environment.

In 1994, Dr. V. Jayaraj of the Government Museum, Chennai spent three weeks in the British Museum Department of Conservation working with the Conservation Scientists and Conservators, focussing on the scientific examination and conservation of the *Amaravati* sculptures. During this period at two half day meetings all of the potential sources of damage to the sculptures and possible methods of ensuring their long term preservation were discussed. The approach taken at the British Museum to the conservation, storage and display of all porous stone sculptures in the collection was found to be applicable to the *Amaravati* sculptures.

Scientific Investigations 1969-1972

In 1960, an investigation into the alteration of the sculptures in Madras and in London was carried out. Reports were produced

by S. Paramasivan, Government Chemist with the Archaeological Survey of India and by A.E.A. Werner, Keeper of the Research Laboratory at the British Museum. In his report dated 24th May 1960, Paramasivan states²:

'...when the sculptures are removed from their original home to places like the Madras Government Museum or to the Indian Museum, Calcutta, they lose their greenish tinge and develop a white incrustation. They lose the sharpness of their decorative details and the aesthetic appeal, which they have always for us. The white incrustation has developed on all the sculptures, which were removed from *Amaravati* and other places and transferred to Madras and Calcutta etc. Some of these sculptures are subject to exfoliation, whereby the disintegration becomes even more rapid.'

The report attributes the alteration of the stone surface to the high relative humidity in Madras, Calcutta and London when compared to that at *Amaravati* and to dissolution and re-precipitation of the limestone by the chemical action of carbon dioxide and water. It also suggests that the sculptures in London may have been affected by the industrial environment resulting in sulphation of the surface.

In a report dated 21st April 1961, Werner presented the results of analysis of the white powdery incrustation³. By micro chemical analysis, it was found to be calcium carbonate and was confirmed as present in the mineral form calcite by x-ray diffraction. Chlorides and sulphates were found to be absent. The white powder was also reported to be present in areas of fresh fractures. Werner concludes:

'These observations indicate that the deterioration, which these sculptures exhibit is not due to the presence of either soluble salts in the stone or the action of atmospheric contaminants such as sulphuric acid. It would appear that the stone has an inherently weak structure due to incipient metamorphosis of the limestone. This might explain why the stone remains stable at *Amaravati*,

but starts to deteriorate when exposed to different atmospheric conditions in which there are fluctuations in the relative humidity and temperature.

It is recommended, therefore, that these sculptures should be kept under stable atmospheric conditions in which the relative humidity is not allowed to exceed 50% so as to reduce the solvent action of atmospheric carbon dioxide.³

Further analysis using different, more sensitive techniques was carried out on five of the sculptures in 1972. The % of acid insoluble (non calcium carbonate) content and the % of soluble chloride content of the stone were determined. The % of sulphate present in surface scrapings was also determined. The acid insoluble matter content was in the range 7.4 - 10.6%. The soluble chloride content was in the range 0.52 - 0.66%. The sulphate content of surface scrapings was determined with less accuracy, but was found to be approximately 5% on two of the sculptures, and 20-30% on three others. There was no direct correlation between the extent of apparent sulphation and the condition of the surface. At this time there was no possibility of identifying the acid insoluble matter, but it was considered likely to be a clay and the potential for the clay to hydrate with an associated volume change was a likely contributor to deterioration.

Based on these analyses, 10 years apart, Werner recommended that the sculptures be kept in an environment with the relative humidity controlled to 30-40% and the air filtered to remove sulphur dioxide.

Scientific Investigation 1983

In 1983, a fuller investigation of the chemistry and geology of the stone and the nature of the clay was undertaken, together with further analysis of deteriorated surfaces⁴. A macroscopic examination of some of the sculptures and a hand sample of the stone, indicated that much of the surface loss and spalls had occurred along cleavage planes in the stone. Particularly greatest

loes was apparent on sculptures where the stone had been carved parallel to the cleavage plane. A petrological examination was undertaken by Dr. Ian Freestone, British Museum Department of Scientific Research. A polished thin section was prepared at right angles to the cleavage planes from a hand sample of the *Amarnati* stone. Viewed under a petrological microscope the directional nature of the stone was apparent, presumably resulting from pressure and heat during a low grade metamorphism. The stone was composed predominately of fine grained calcite, c 20 μ , across, with coarser aggregations of calcite and quartz present. Thin folia of a third mineral phase, a mica or clay mineral were present at a frequency of greater than one major folia per millimeter. These layers represent planes of weakness in the stone and are responsible for the cleavage.

The nature of the acid insoluble matter content of the stone was investigated using x-ray diffractometry and scanning electron microscopy (SEM). By x-ray diffractometry three minerals were identified as present, quartz, chlorite and illite. The thin section was examined in the scanning electron microscope and two types of clay mineral were seen to be present in the folia. In one, the elements potassium, aluminium and silicon were present, corresponding to the illite detected by x-ray diffractometry. In the second, the elements potassium, aluminium, silicon, magnesium and iron were present, most probably corresponding to a biotite mica. Small quantities of chlorite sometimes associated with quartz were present throughout the stone, this green silicate mineral being responsible for the green colour of the stone.

In 1989, acid insoluble matter samples from the 1983 investigation were re-analysed and the possibility that the illite could be muscovite was raised. In 1994, three more of the sculptures in the British Museum collection, and three from Madras were analysed. Both x-ray diffractometry and SEM analysis were carried out. The improved analysis facilities on the SEM, allowed a ratio of elements present to be determined and

the ratio of potassium to aluminium in the clay previously identified as illite indicated that the clay was in fact muscovite⁵. Samples were taken from the surface of six sculptures for analysis by x-ray diffraction. All of the samples contained calcite and quartz and three contained gypsum, indicating that sulphation had occurred. However, there was no evidence of continuous layers having formed on the surface of these sculptures or of continuing sulphation. SEM examination of several samples taken from fracture surfaces of sculptures suggested that dissolution and re-precipitation of calcite may have occurred. As with sulphation, this would have contributed to the powdery nature of the surface of some sculptures.

Environmental Conditions for Preservation

The results of the scientific investigations suggested that there were five potential causes of deterioration of the sculptures.

- ❖ The cleavage planes created by the folia cause the stone to split readily when knocked hard and hence subject to damage from poor handling.
- ❖ The clay minerals in the stone are subject to softening and possible volume change at high relative humidity, causing separation of folia close to the surface and flaking of the stone.
- ❖ Soluble chloride in the stone is subject to dissolution and re-crystallisation cycles with fluctuations in relative humidity causing disruption at the surface of sculptures.
- ❖ Calcite is subject to dissolution and re-precipitation by reaction with carbon dioxide and water at high relative humidity causing disruption at the surface of the stone.
- ❖ Calcite reacts readily with the pollutant gas, sulphur dioxide in the air forming calcium sulphate (gypsum) and creating a powdery surface.

To control the deterioration mechanisms, the *Abarat* sculptures in the British Museum collection were stored in an

air-conditioned room with filtration to remove sulphur dioxide and a temperature range of 18 - 20°C, and relative humidity range of 30 - 40%. Under these conditions, the sculptures remained stable. There has been no loss of surface or further sulphation of the surface. When the sculptures were put on exhibition in the Asahi Shimbun Gallery of *Amaravati* sculptures, these conditions were adopted.

Building and Access Considerations

Apart from the potential for handling damage because of the cleavage planes in the stone, four of the potential damage mechanisms are promoted by water.

There are many sources of moisture in buildings and these must also be controlled since massive deterioration can be caused if the sculptures become wet and remained wet. Good building maintenance is important. If possible, walls should be constructed with a damp course or a chemical damp course inserted. Pointing of walls should be in good order. Gutters and drain pipes should be well maintained. Water should be drained away from the base of a building.

Within the museum whenever a sculpture is fixed to a wall, a damp proof membrane, or lead sheet, should be placed between the sculpture and the wall. This prevents ground water from moving through the wall into the sculpture. Cement or plaster of Paris should not be used in the fixing of sculptures because they are both sources of water and soluble salts. As they dry water migrates from cement and plaster of Paris into the sculpture carrying salts with it, mobilising soluble salts already present in the stone and hydrating clay minerals. Polyester or epoxy resins can be used to fix or repair sculptures in place of cement or plaster of Paris. Dust should not be allowed to build up on the surface of sculptures because it can hold water onto the surface of the stone, promoting decay. The public should not be allowed to touch the sculptures since moisture, soluble salts

sand dirt can be transferred from hands to the sculpture surface. All of these factors have been taken into account in setting up the Asahi Shimbun Gallery of *Amaravati* Sculptures.

Conclusions

A well maintained building and a controlled environment have provided good conditions for the preservation of the *Amaravati* sculptures in the British Museum. However the tight environmental control, which can be achieved as a temperate climate is not always possible in climates where extremes of temperature and humidity prevail. The most important factors for the preservation of the sculptures are good handling protocols; maintenance of the building to prevent ingress of water; separation of the sculptures from the fabric of the building to avoid migration of ground water; removal of plaster of Paris repairs from the sculptures because these cause local decay, and a stable relative humidity to prevent crystallisation cycles of the soluble chloride and hydration cycles of the clay minerals.

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Science Behind the Conservation of Stone Objects

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Stone has taken an important part of our culture as most of the art pieces are chiseled in stone and we are in the danger of looting them. Stone have been used by ancient people for recording, embellishing, preserving facts of their lives and spiritual and artistic visions as well as satisfy their practical needs for shelter, protection and secure storage. Most of the authentic records of the history were carved in stone. Stone were used in construction of buildings from very ancient times. Temples, tumuli, pyramids and other edifices and sculptures made of stone are contributions of vanished societies. These seem to be compellingly awe inspiring and thrilling to many generations since their creation. Stone is a durable material and remains in good condition for a long time. Despite being durable, stone objects deteriorate due to age and they need to be preserved. There are various methods of conservation and restoration. This paper deals with the science behind various deterioration and methods of conservation and restoration.

Sources of Stone Objects

Building stones, stones for inscriptions, stones for making sculptures and other tools used by the ancient are obtained from rocks. The rocks are made up of grains of one or more minerals. Minerals can be defined as naturally occurring homogeneous, inorganic substances having fairly definite chemical and physical properties. The properties of rocks are then governed by the properties of minerals present in its structure. Rocks differ in

appearance and other properties on account of constituents present, their abundance, their size and arrangement pattern etc. The stone objects in the Government Museum, Chennai are received through various means such as field collection, gifts, loans, confiscation, transfer, as stray finds under the Treasure-trove Act etc. The Government Museum, Chennai came into existence with the collection of a few hundreds of geological specimens in 1851. The Archaeology section of the museum has a very good collection of stone sculptures, metal sculptures and terracotta figurines. The sculptures range from 2nd Century B. C. to 15th Century A. D. and are rare in many aspects. The Chemical Conservation and Research Laboratory of the Museum is tackling the problems of their preservation.

Stone Sculptures

The sculptures belong to various periods, vary in styles and are made of different types of stones. Stones are parts of rocks. Rocks and minerals are in abundant and consist of silicate units. The main silicates are of sodium, calcium, magnesium rocks and aluminium. There are various viz., Igneous, Sedimentary and Metamorphic rocks in the earth's crust.

Igneous rocks are formed by the solidification of molten magma inside the earth. Examples of igneous rocks are granite, basalt. They are generally stable under a variety of conditions. Granite contains over 66% of silica and is an acid rock. There are various granites like granite gneiss, biotite, granite and dolerite.

Sedimentary rocks are formed by the deposition of products of weathering on the pre-existing rocks. Examples of these rocks are limestone, sandstone, shale etc. The *Taj* of *Aminabad* was made of limestone. The National Art Gallery building of the Government Museum, Chennai has been clad with red sandstone from *Saturnia* in Andhra Pradesh.

Metamorphic rocks are formed by the change of character of the pre-existing rocks. The igneous and sedimentary rocks are

changed in character when they are subjected to great heat and pressure. Examples of this variety of rocks are gneiss, marble, schist, quartz, slate etc. The Taj Mahal is made of marble. Most of the sculptures are cut out of gneiss.

Based on the chemical properties, the rocks can be classified as follows:

Siliceous Rocks

Rocks, which contain maximum amount of silica, are called siliceous rocks. E.g. Granite, quartzite.

Argillaceous Rocks

Rocks, which contain argil or clay predominantly, are called argillaceous rocks. E.g. Limestones, slates.

Calcareous Rocks

These rocks, which contain calcium carbonate predominantly, are called calcareous rocks. E.g. Limestone, marble.

Reasons for Deterioration

Materials of nature deteriorate continually as a result of physical, chemical and biological processes. The stability of stone is mainly dependent on its internal structure and petrographic composition and also to the environment to which it is exposed. The decay may be due to the following reasons:

Decay Due to Quarrying: The decay in the stone objects can be due to the method of quarrying or dressing. The microcracks developed will further deteriorate the stone objects.

Due to Dampness: Dampness is one of the agents of the decay in stones. The moisture absorbed will help the stone to take in the salts, which result in surface damage of the stone objects.

Decay Due to Soluble Salts: The salt absorption by the stone objects creates surface crumbling of the objects due to the crystallisation internally.

Decay Due to Temperature Changes: Rapid changes of heat due to sun and the sudden rain cause strain between the outer and inner portion of the rocks or stones, which results in breaking of the specimens.

Decay Due to Atmospheric Pollution: Atmosphere consists of pollutants such as carbon-di-oxide, sulphur-di-oxide, nitrogen oxides, hydrogen chloride, hydrogen fluoride, hydrogen sulphide, aerosol, suspended particulate matter get dissolved in the moisture and are absorbed by stone objects once again resulting in the crystallisation thereby in the surface crumbling. Much disfiguration of stone buildings occurs by the accumulation of soot deposits. The tarry matter present in soot, causes it to adhere tenaciously to any material with which it comes in contact. Hence in towns, particularly, much disfiguration of buildings occurs due to the accumulation of soot deposits. With the limestone, slow erosion occurs in the areas, which are exposed to the prevailing winds. This prevents the retention of the soot and only the sheltered sides become blackened. In an average sample of household soot, Knecht found 10.7 % of ammonium sulphate and 10.9% of acid constituents. But in addition to its blackening effect, soot also contributes to chemical decay, because it carries with it free acids and soluble salts, which it brings into contact with the stone. The absorption of the soluble salts by stones is through the capillaries. When the salts get crystallised, they appear at the mouths of the capillaries and make the surface at the mouth to crumble. Banded objects absorb soluble salts and when the salts crystallises, the stones disintegrate.

Decay Due to Moss and Lichen: The decay due to moss and lichen etc., is caused only in the case of stone objects exposed to rain. Acids generated by moss and lichens not only damage carbonaceous stones but also attacks silica and cause damage on the surface.

Deterioration Due to Growth of Vegetation: The growth of vegetation causes damages only in the case of structures and

exposed stone monuments. The vegetation growth withdraws water and retains the moisture inside the structure thereby by damage is created in the stone monuments. The deterioration of stone objects under the influence of atmospheric conditions, usually starts by graying of the stone, often followed by crusts and further destruction by scaling etc. For efficient cleaning and preservation our knowledge about these external layers must be as complete as possible. The crusts arise from environmental effects in the case of marble primarily from sulphur dioxide.

Condition of the Amaravati Lime-stone Sculptures

The soluble salts absorbed by the limestone sculptures in the *Amaravati* Gallery of the Government Museum, Chennai were removed by poulticing using moist and neutral paper pulp applied to the surface of the sculpture. In the case of the affected loose sculptures, after all the salt present are removed by immersing the sculptures in de-ionised water and a preservative coating of 2% solution of poly vinyl acetate in acetone was applied. Since these sculptures are embedded on to the brick-lime constructed walls of the gallery, they showed further crystallisation of salts due to the absorption of moisture by seepage and leakage and external wetting of the walls due to rain. The seepage is more due to the high level of water table in the area due to the presence of a water tank near the building. Therefore, now a days no coating is given but these affected sculptures are removed off the salt by poulticing with paper pulp. Action is being taken to remove the sculptures



Limestone Sculptures Embedded into the Wall

from the walls. Now three pieces have been removed from the wall on an experimental basis. This was successful. The removal of the sculptures is a laborious process. The conservation process has been started to remove the soluble salts by immersion in pure water.

Marble Sculptures

Marble is a strong variety of stone, which basically consists of calcium carbonate. It is a metamorphic rock and also a calcareous rock. The Government Museum, Chennai has only a few of marble sculptures. They are not on display except one in the anthropological gallery. They have only accumulated dirt on them and they have been very easily cleaned with the help of a detergent and ammonia solution. The detergent softens the dirt and removes it. Ammonia accelerates the softening and easily evaporates soon after it softens the dirt. The loose dirt is removed with cotton swabs. This laboratory handled many marble sculptures in the St. Andrew's Church, Egmore, Chennai and St. George's Cathedral, Chennai. In the conservation work done in the St. George's Cathedral students from Stella Mare College were used. In the cleaning of the marble sculptures and tablets Tripol, ammonia and oxalic acid were used to remove superficial dirt, stain and iron stain respectively. The surface was dried and no coatings were given as they are well with in the church.

Granite Sculptures

Granite is one of the igneous rocks. There are over 500 granite sculptures in the Government Museum, Chennai both in the reserve collection and on display. Granite sculptures are affected by dirt, oily accretions, salt action etc. Due to human touch effected by the visitors, most of the sculptures have been blackened at certain specified spots. Even though these areas are resistant to water percolation and vulnerable to chemicals and pollutants, these spots completely mar the aesthetic beauty of the sculptures. Sometimes the oily accretions are so deep that it is

very difficult to remove them if allowed to remain on the surface. Especially the sculptures in temples are affected by the application of oil and associated materials used during the worship of the sculptures.

Traditionally, different types of preservative methods were used to clean the oily accretions formed over the surface of the granite stone sculptures in temples. They are flour preservation, sandal preservation etc. They are nothing but the poulticing practised to day. Even though some traditional procedures are good in preserving the organic materials, some procedures are deleterious to stone objects. Sometimes people, who want to preserve the objects in their possession, damage them without proper knowledge about the conservation. Whitewashing the stone walls, which have the sculptured portions, arises due to ignorance. Oil is poured or ghee is placed on the sculptures, which are absorbed by stone and this attracts dust etc., and the stain is permanent.



*Anbanattanan, Granite
Sculpture in Marney
Palace*

The Chemical Conservation and Research Laboratory of the Museum has helped the Central Institute of Plastic and Engineering Technology, Chennai to preserve a large sized *Siva* sculpture made of granite by poulticing by paper pulp and coated with 2% solution of poly vinyl acetate dissolved in acetone as the sculpture is under a tree out side the institute but inside the campus. Stella Mars College history students were involved in clearing a temple in Chennai and in the Government Museum, Chennai. Students from the Madras Christian College, Chennai were provided with a short training in Conservation of Stone Objects and were involved in the cleaning of the stone sculptures during the 150th Year Celebrations of the Government Museum,

Chennai. The Chemical Conservation and Research Laboratory of the Museum took up a special conservation work at the *Pandharpur Temple*, Cuddalore with the help of the public and students with the supervision of the conservation team of the Chemical Conservation and Research Laboratory of the Museum.

Sculptures Made of Schist



Gandhara Buddha

Schist is one of the metamorphic rocks. This type of stone is easy to carve out sculptures but are not strong enough and are not durable. The deterioration is faster. The binding between the layers get easily lost and hence the disintegration. Some of the sculptures from *Pakistan* and *Gandhara* displayed in the Sculpture Gallery of the Museum are in good condition. But some are badly damaged and few have been restored, conserved and saved for posterity. These sculptures are coated with lime and appear white in many spots. This has preserved the sculptures from various outside agencies of deterioration. *Parsons cement* and *Mortar* were used in those days to restore the broken sculptures.

The Chemical Conservation and Research Laboratory of the Museum once conserved one schist stone object of *Vishnu*. The disintegrated layers were fixed with the help of poly vinyl acetate and it is maintained well for the past fifteen years. Normally, the salts present in small sculptures are removed by immersion in distilled water. In case they are embedded into the walls, the absorbed salts are removed by poulticing. Now a days different types of slanes are available and the variable slane is used as it simulates the characteristics of the stone.

Soapstone Sculptures

The temples at *Belur* and *Halebid* in Andhra Pradesh are made of soapstone. Some of the sculptures from Belur in the Chennai Museum are made of soapstone but they are in good condition. Only problem is that they are scratchable. In one of the soapstone objects, a very careful restoration has been done very long back using heartwood, which simulates soapstone. Unless told, it is very difficult to find out the restoration.

Conservation Treatment

There are different types of conservation treatment. They are

- ◆ Physical treatment and
- ◆ Chemical treatment

Some methods cannot be adopted to clean all types of objects. Depending upon the nature of the stone and type of decay, the treatment of stone objects differ.

Physical Treatment

Stone objects, which are covered with dust etc., are cleaned by soft brush. If the dust has become dirt, then little of moisture is used to remove the dirt. In case of well-adhered dirt, *Tapeal*, *Lakshar*, *Excess*, etc., solution may be used to soften the dirt. In case of fine stones, which are affected by moss and lichen they are normally removed by sand blasting in our country. This affects the stone by removing layers of stone along with the moss and lichen deposit. Removing the deposits by hard metal brush by all means should be avoided.

In case of the stone objects, which were found buried and affected by salts, polishing by neutral paper pulp or *Sepadit* removes the soluble salts. This is a very good method. Immersion



*Polished
Thanthabara Sculpture
(Soapstone)*

of small objects in pure water cleans soluble salts from the affected sculptures. The washings should be tested for the presence of salts, especially sodium chloride. The stone objects in temples are still traditionally preserved by methods called "*Masabhapu*" (flower preservation), "*Sandhanabhapu*" (sandal preservation) etc. These methods are nothing but poulticing. Now a days various materials such as Fuller's earth, paper pulp, *Spiessate* etc., are used in the chemical conservation laboratories in removing the oil accretions along with solvents.

Steam cleaning is also done in some laboratories both in hot and cold conditions. This softens the dirt and removes it by wiping out with cotton. Detergents are used to remove the dirt in certain cases.

Laser Cleaning

The major disfiguring deposits on outdoor statues are generally crusts of black carbon particles from vehicle and power station emissions. On limestone and marble statues, acid rain builds a layer of gypsum as it converts the calcium carbonate in the stone to calcium sulphate. Laser tools work because laser energy leads to localised heating of the crust, which then breaks away without damaging the stone below. This is better than sand-blasting and chemical cleaning and other methods of physical cleaning.

Cleaning Methods

Cleaning of stone objects or monuments, sculptures, inscriptions or structural edifices in stone is required not only to have aesthetic look but also to ensure better preservation of stone objects. Cleaning methods can be classified according to the principles or the techniques involved in the method.

Water-based Methods: Water sprinkling, water spray with or without pressure, or very fine water spray along with brushing and washing. Poulticing is also a water-based method. Water acts as a very important agent in cleaning of stone objects.

Steam Cleaning: Either cold steam or hot steam with pressure can be used to remove the surface accretions from the stone objects. Dirt is very easily removed from limestone and marble sculptures and structures by steam cleaning.

Mechanical Methods: Both wet and dry grits can be used to blast off the accretions. They are wet grit blasting, dry-grit blasting, micro blasting and sand-blasting. Sand-blasting is now-a-days widely practiced in Tamil Nadu by the temple authorities to remove the white washed layers from the stone walls.

Chemical Methods:

Chemicals are required to remove the stains from the sculptures. It is better always to use very dilute solutions of the chemicals. Care should be taken before any chemical is used. Some of the chemicals will cause permanent scar on the sculptures. Whitewash mark are removed by the gentle application of very dilute solution of acetic acid using cotton swabs and removing them with ammonia after physical abrasion



Removal of Moss and Lichen from Stone Sculpture

Moss, algae and lichen-affected sculptures need chemical cleaning. The black patches from sandstone slabs are removed with the help of zinc silico fluoride mixed with few drops of hydrofluoric acid. Citric acid is used to remove the black and green patches found on the marble monuments. Hydrogen peroxide solution or ammonia with gentle brushing with a tooth brush will remove the deposit. Washing with water removes off the dark solution from the stone objects. A 1 % solution of zinc silico fluoride coating over the stone sculptures will avoid further plant growth. Application of organic solvents like rectified spirit removes very

easily the oily secretions from the stone sculptures. Morpholine removes the soot from the sculptures. Droppings of birds are removed using physical methods and washed with organic solvents and cleaned with detergent solution followed by thorough washing with distilled water and drying.

Restoration of Stone Objects



Restored Stone Elephant (Vijayanagar) Blochschauer

Restoration is often necessary for reasons of safety of the stone objects and is carried out using modern materials in a manner sympathetic to the existing structure, but not necessarily identical with it. Dowsing can be done in the case of broken stone objects

by joining the pieces by means of stainless steel headless rods. The stone objects should never be in contact with the ground. A moisture barrier should be kept in between the masonry structure and the objects. In the museums in Tamil Nadu both wooden and masonry structures on the floor of the galleries are made to display the large and heavy sculptures.

Consolidation

When stone sculptures are very weak and fragile, consolidation is required. Consolidation is nothing but fixing the loose materials together. A 5-10% solution of poly vinyl acetate in acetone serves as a very good consolidant. Silanes are also used as good consolidants. After the stone objects are treated, it is better to give a protective coating of poly vinyl acetate over them. Once in two years, the protective coating may be given. Consolidation of weak stone objects can be done with the help of acrylic resins like perspex, polyester, epoxy resins like poly vinyl acetate, poly vinyl chloride, *Araldite*, which are some of the consolidants in

Science behind the Conservation of Stone Objects

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Broken Gandhara Buddha (Shree)



Luxurious Sculptures Embedded in to the Wall of the Amaravati Gallery



Salt Affected Sandstone Sculptures in Kandharpuram



Salt Affected Sandstone Sculptures in Bhadrachalam



Weathered Sandstone Sculptures in Bhadrachalam

Science behind the Conservation of Stone Objects

- V. Jeyaraj



Students of the Care of Museum Objects Programme at the Shree Temple working with Paper Pulp



Altered Limestone Sculpture in the Anamaram Gallery is being Poultriced with Paper Pulp



Offshoots Who Attended the Capstone Course on Conservation of Cultural Heritage are Cleaning a Temple Wall Chemically



Offshoots Cleaning Limestone from a Temple at Thiruchengodu, Salem District



Stone Sculptures before and after Restoration



Amazonite Sculpture Conserved by Treating with Dental Wax

use. Recently Paraloid B72 is very commonly used. Organosilanes are largely used in the consolidation of stone objects.

Normally, dilute solutions of epoxy resins have been used successfully in the past to consolidate deteriorated porous stone objects. By this method, the resin darkens and they are proved to be deterrent to the wider use of these materials by the Conservators. But, solvent washing to remove surface deposited resin and exposure to sunlight are effective methods for restoring the original visual appearance of consolidated outdoor stone.

Conclusions

With the idea of preserving our cultural heritage, the Government Museum, Chennai is giving training to those in charge of cultural heritage on Care of Museum Objects. Recently a training programme for the Executive Officers of the Hindu Religious and Charitable Endowment Department was also conducted to take care of the monuments and antiquities under their charge. Besides these, the Chemical Conservation and Research Laboratory of the Government Museum, Chennai has undertaken many training cum conservation programmes in temples. In 1996, the Madras University has recognised the Chemical Conservation and Research Laboratory as a research laboratory to conduct research leading to Ph. D. Degree. Those who are interested in conservation may approach the museum to avail such facilities. A Conservation Gallery is set up in the museum to create awareness on conservation and preservation of our cultural and art objects. Let us preserve our treasures for posterity.

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Lasers for the Conservation of Cultural Heritage

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The laser is now in every day use for a range of applications due to the special properties of laser radiation. A laser is a source of electromagnetic radiation, which is directional and unlike most light sources, monochromatic (has a single wavelength). The applications of lasers in conservation rely on the properties of absorption and reflection of the beam of laser energy. Techniques such as laser cleaning make use of light absorption to selectively remove layers of unwanted material. On the other hand, techniques such as holography and laser scanning make use of the light reflected from the surface of an object. This paper aims to provide an introduction to the use of these optically based techniques in the conservation of stone objects.

Laser Cleaning

Laser cleaning was first used in art conservation during the 1970s. The results obtained were very impressive, but unfortunately further work was limited by the technology and the high cost of lasers. In recent years, interest in laser cleaning has been revived as lasers have become more reliable, portable and affordable. This has led to successful research into the use of lasers for cleaning a wide range of artefacts, including objects made of stone, terracotta, bone, ivory, vellum and some metals². The laser is now no longer a research tool and is used in the every day work carried out at the studios of the Conservation Centre of National Museums and Galleries on Merseyside (NMGML).

Lasers are normally named after the material used to produce the laser energy. In the case of art conservation, the most commonly used cleaning laser is the Nd:YAG laser. This laser produces pulses of infra-red energy that are directed on to the surface to be cleaned, usually by means of either mirrors or optical fibres. The laser energy is absorbed by foreign material, which is then ejected from the surface. The laser pulses used are of very short duration, which ensures that the cleaning effect is localised to a precise region and does not damage surrounding areas. The precise and immediate nature of the technique gives the Conservator a degree of control over the cleaning process not previously possible, thereby allowing for the preservation of delicate surfaces and patinas. In many cases, such as the cleaning of limestone³ and marble⁴ sculpture, the process of laser cleaning stops as soon as the dirt layer has been removed. This 'self-limiting' action operates because the black dirt or pollution layer strongly absorbs the laser radiation while the surface beneath reflects the beam harmlessly away. Problems of over-cleaning can therefore be avoided. The laser system is most effective when there is a distinct difference between the absorption properties of the accretion layer and the substrate layer. When this does not occur, then great care must be taken during cleaning to avoid damage to the substrate. The laser affects only the surface of the object being treated and therefore is unlikely to give satisfactory results when attempting to remove material trapped within the matrix of the substrate, so for example, while the laser may be effective at removing salts from the surface of a stone object, it will leave untouched any salts within the object.

Laser Cleaning

The laser cleaning system is capable of operating both in the conservation studio and *in situ* for architectural sculpture. The figure shows a marble relief during the process of laser cleaning in the conservation studios of NMGM.

The main benefits of laser cleaning are detailed below:

- ❖ **Control:** The laser provides the operator with unrivalled control over the quality, degree and rate of the cleaning process. Unlike chemical methods of cleaning, the effect of laser cleaning is immediate and stops the instant the beam is removed from the surface.
- ❖ **Precision:** The laser beam is delivered through a pen-like handpiece, so that the laser cleans only where directed. By controlling the working distance of the handpiece it is also possible to obtain precise control over the size of area cleaned.
- ❖ **Non-contact:** The laser cleaning technique requires no physical contact with the surface of the object, allowing even very fragile surfaces to be cleaned.
- ❖ **Speed:** The use of lasers provides two advantages over traditional cleaning techniques. Firstly, the user can control the number of laser pulses per second allowing either rapid or careful cleaning. Secondly, the laser is easily portable and requires very little time to set up.
- ❖ **Environmentally Friendly:** The laser cleaning process generates a minimum of waste products, the dirt ejected from the surface can be easily collected using an extraction system³. No hazardous chemicals or solvents are used in laser cleaning so that the only protective items necessary are safety glasses and a face-mask.
- ❖ **Reliability:** The laser is reliable, easy to use and requires very little maintenance.



Laser Cleaning of a Marble

Laser Scanning

In addition to the need for careful conservation treatments, the unpredictable nature of the world means that there is a pressing need for proper records of artworks to guard against their loss from forces as diverse as pollution and terrorism. For many years the method of recording three-dimensional (3D) objects has been dominated by photography. The principal problem has always been one of trying to adequately represent such 3D objects using a 2D method. Now, however, the acquisition of 3D data is possible using 3D digital cameras and laser scanners⁶. These devices create 'clouds' of data points that map out the surface of an object and can provide a record of a 3D surface down to fractions of a millimetre. The recorded data is stored on computer and may be viewed by means of software that can translate this quantifiable information into a visual representation.

The laser scanner comprises a low power laser that is directed onto the surface of an object and off-axis position sensor for collecting the reflected light. A position measurement is carried out by a simple application of trigonometry, determined by the geometry of the laser beam relative to the sensor. The laser beam is moved across surface of the object and the resulting dense cloud of data points provides a digital representation of the object. For a complex object, it is often necessary to carry out measurements from several different directions and angles.

Laser scanning provides many advantages over traditional recording techniques. It is not, however, without problems. For the scanning process to be effective the object surface must be sufficiently reflective to enable accurate recording. To correct this problem, laser power and detector sensitivity can be increased or a laser emitting light of a different wavelength could be used. The topography and size of the object to be recorded also influence the ease with which an object can be scanned. Complex objects with undercuts tend to obscure parts of the surface of the object while large objects tend to produce correspondingly

large computer data files, which can be difficult to store and manipulate. The problem of topography can often be overcome by making multiple scans from different directions and then linking the scanned data within a computer. Computer software can also be useful in reducing the size of data files collected by allowing the user to vary the resolution of the scan according to the level of detail in an area.

The scanned image represents a comprehensive record of an object, which is permanent, versatile, accurate and above all, the technique causes no damage to the original object. A scanned image records the physical condition of an object at an instant in time. The data set representing the object is far more portable than the real object and can be an invaluable tool for academic study⁷. The reproducibility of the technique also makes possible the monitoring of the physical condition of an object with time.

Non-contact Replication

The replication of 3D works of art has not changed in concept for many years. Traditional techniques rely either on the creation of a mould from the surface of artwork or on copying by eye by a sculptor or craftsman. Both techniques are however fraught with potential problems.

The use of moulds requires considerable contact with the surface of the original artwork. In many cases this can not be considered safe practice since the surfaces of many artworks are not only fragile but may contain important detail or remnants, which provide an art historical context for the piece. It is therefore of the utmost importance that the surface of artworks should only suffer contact when no other options remain. The use of moulds is also limited by two other factors. Firstly, the range of materials available, which can be used to cast replicas is limited and may possibly not be sympathetic to the original. Secondly, when a mould is used, there will inevitably be shrinkage in the casting

material leading to a slight but distinct size difference between the original and copy.

The copying of artworks by eye does not have the problems of contact associated with moulding. It is however not an accurate technique but depends on the skill of the sculptor and is therefore a re-interpretation rather than a replica.

What is required then is a method of non-contact replication that provides an accurate but flexible method for the replication of 3D works of art. The advent of digital measurement systems and modern manufacturing techniques provides a potential solution to these problems. At the heart of the problem of non-contact replication is the ability to translate objects in the virtual space of the computer into 3D. This is a well-known problem in a modern industrial context, for example in the automotive and aircraft industry, where many complex 3D objects exist as computer models and physical prototypes must be made prior to production. There are many automated devices that can translate 3D computer models into a tangible form. The most common is Computer Numerical Control (CNC) manufacture that involves machining, using a multiple axes lathe or laser, into a wide variety of materials. In many cases, CNC manufacture provides an excellent solution to the problems of non-contact replication⁶ and replicas can either be cut into traditional materials (e.g. marble, limestone, wood) or modern materials (e.g. resin, plastic). Replicas can be machined very accurately using scanned data and if required, in material, which is sympathetic to the original. Advances in computer technology and engineering techniques now mean that it is possible to achieve sub-millimetre accuracy.

There are cases where CNC manufacture cannot easily provide a solution, such as when there are very complex forms and undercuts, which occur in many sculptural works. A different kind of industrial process could provide an answer to the requirements of non-contact replication, this process is known as layer manufacture. The development of layer manufacturing techniques

grew out of a need to reduce time scales for the production of physical prototypes of computer models. This is still a relatively new area of technology that emerged in the mid 1980s. The computer data is sectioned into a number of adjacent cross-sections or layers. The cross-sections are then systematically created through the solidification of either liquids or powders and combined into a 3D form. The range of materials is wide and is also rapidly increasing and includes plastics, wax, sand, resin and paper. The main drawbacks of the technique are that there are still limits on range of materials available, restricted production volumes and high costs.

Conclusions

The laser provides the Conservator with a cleaning tool of exceptional precision and control. In a number of conservation studios across Europe, laser cleaning is now considered routine and sits happily alongside more conventional techniques, such as steam cleaning and solvent cleaning.

The technique of laser scanning has a wide range of applications in the field of conservation. In addition to applications such as replication, the building of libraries of scanned images offers exciting possibilities for the creation of virtual museums and opportunities for academic study at a distance.

It is now possible, using the latest technology, to create high accuracy replicas. Computational and technology requirements are high and therefore costs are also likely to be correspondingly high in the short term. Further developments will be necessary before large-scale architectural sculpture may be routinely replicated. Nevertheless, the capacity for accurately recording and replicating works of art is now broadening as technology advances. It is clear that replication techniques will become increasingly important, as today's hostile environment increasingly requires the removal and replacement of important architectural sculpture.

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Preservation and Conservation of Stone Antiquities Using Lasers

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Historic preservation and conservation are complex fields, a blend of art, history and science. Diverse applications can stretch from pest control in historic homes to pigment examination in a Japanese painting, from consolidation of a friable archaeological sherd to storage of a video montage. Such a multitude of materials and techniques has given rise to a wide variety of terms across the preservation and conservation disciplines. Cleaning is a critical part of the conservation process. It serves not only to improve the aesthetic appeal of an object or building but also to reveal its true condition so that appropriate action can be taken to ensure that it survives for many future generations to enjoy.

Conventional Methods of Sculpture Cleaning

Until the mid-1960s, painting Conservators led the whole field of conservation with their technical expertise and experience. Today that imbalance has shifted and it is in the field of sculpture conservation that many of the most complex and exciting technical developments are taking place. During recent years, there has been increasing concern over some of the more conventional methods of cleaning used on sculpture and sculptural decoration on historic buildings and partly to the rapid development of more sophisticated synthetic resins for use in repair.

Careless and inappropriate use of techniques, such as air-abrasive and steam cleaning, can lead to severe damage of the underlying stone surface. The loss of surface detail by over thorough cleaning can reduce the visual appeal of a surface and in extreme cases can even lead to its accelerated decay. Even if cleaning is carried out very carefully, techniques such as air-abrasive cleaning will result in some loss of material from a surface, particularly from a decayed crumbling surface, simply because abrasive particles cannot discriminate between the soiling and the stone surface. The removal of black encrustation from limestone sculpture is usually accompanied by removal of the patina, which develops on the surface over a period of time and within which the original surface relief is preserved.

Chemical-based cleaning techniques also have associated problems: chemicals often leave residues within the stone, which can cause problems later on, and once they have been applied their reaction cannot be suitably controlled. In Glasgow, some sandstone buildings, which were chemically cleaned a few years ago are turning green at an alarming rate since ideal conditions for algae growth have been created on the surface.

The realisation that the heritage of stone sculpture and buildings might not remain in a recognisable form for more than another 50 years has stimulated an interest in the conservation of sculptures that would not have occurred were the problems merely confined to museum collections. New pressures also are being exerted on museums. As the main centers of conservation expertise, they are called upon to lend their aid to the organisations dealing with these problems in cathedrals, churches and historic houses. They also act as places of refuge for endangered sculptures. The scale of the problem (the rapid increase in air pollution worldwide and the vast number of sculptures involved) have caused the profession of sculpture conservation to develop rapidly. Although it has been possible to borrow from painting conservation, many surface cleaning

techniques for use on terracotta, plaster and polychrome wood sculpture, very few of these techniques are suitable for marble and limestone, with their particular susceptibility to damage from water and soluble salt migration.

Problems in Sculpture Cleaning

The main problems facing the stone conservator are stabilisation, consolidation and further protection against pollutant gases and soluble salts. Stone is extraordinarily unstable in the modern environment. Once it has been attacked by pollutant gases, such as sulfur dioxide, or migrating salts, such as nitrates or chlorides, it is difficult to return the stone to a stable condition, even when it is placed in a museum environment. Although some temporary stability may be achieved by putting a damaged sculpture in a temperature- and humidity-controlled glass case, it is commonly found that degradation will continue and in certain instances, even accelerate.

To have any hope of halting salination, the stone Conservator must interfere with the deep structure of the stone, sealing it against moisture movement and strengthening it against salt damage to the porous structure. Probably, the most popular means of stabilising stone is the introduction of a consolidant. In the past, consolidants such as wax and shellac have been tried. These do not penetrate deeply into the stone and often aggravate the problem. Various synthetic resins, such as acrylics, epoxies, polyesters and silicones, have been used with greater success. By far the most successful, however, have been the alkoxy-silanes. These have several distinct advantages over other consolidants. They penetrate deeply into the stone (two to three inches in some limestone) and they deposit a hard, almost indestructible network of siloxes in the porous structure of the stone, which waterproofs and strengthens it.

There are many forms of alkoxy-silanes in use and many ways of applying them. The commonest methods are simple brushing,

spraying and vacuum impregnation. Of these, the first is the most controllable and delicate approach, while the last is the least controllable and most potentially dangerous.

The full treatment of a sculpture must, of course, include draining. Any consolidation treatment or attempt to remove salts from stone must be carefully integrated with an appropriate cleaning system. In the past, the most common way to clean and desalinate stone was to immerse it in a tank of water for a period of weeks or months. This process can cause considerable damage because it loosens friable stone and pigment from the stone surface. A better method was developed in the 1960s, by which a dry poultice (magnesium silicate and deionised water) is used to suspend a thin layer of water over the surface of the sculpture, like a cosmetic mudpack, sucking out both dirt and salts. This treatment minimises the contact with water and also does less harm to the fragile surface of the sculpture. The use of sophisticated tools and techniques such as ultrasonic dental scalers and abrasion by air-blasted microscopic glass beads helps to give the Conservator much greater control over the cleaning process. Lasers were first used for removing pollution deposits from stone in 1970. The development of laser-based techniques during the past few years has been a significant advance in making conservation methods less intrusive and more controllable. Improved laser technology, decreasing cost and the concurrent development of fibre optics suggests that it may soon be possible to produce a flexible precision tool that is capable of removing dirt and other encrustation from the surface of sculpture by vapourisation, without harming the stone itself.

Laser as a New Tool

Since their invention in the early 1960s, lasers have found widespread application in metallurgy, medicine, telecommunications and entertainment. Less well known has been their application in the world of historic preservation, where lasers are just beginning to revolutionise the conservation of works of

art. The term "laser" is an acronym for "light amplification by stimulated emission of radiation." A laser is the device that produces a highly directional beam of light in the infrared, visible or ultraviolet region (depending upon the type of laser) of the spectrum. The laser beam can be focused by a lens that concentrates the power on a very small region of the target. Depending upon the intensity of the light, it may be used to cut metal or to selectively remove a thin film of material layer by layer.

This technology has great potential for the cleaning of art works. Many works of art have been subjected to decades, if not centuries, of exposure to the elements, such as atmospheric pollution both inside and outside museums. This has led to a harmful accumulation of grime and other surface encrustation that obscure the underlying surface. Traditionally, art Conservators have cleaned paintings and other works of art with scalpels, abrasives and solvents applied as swabs or poultices. Recent advances in laser technology have yielded new tools for selectively removing unsightly or harmful surface accretions while preserving the underlying surface.

Advantages of Laser Cleaning

From a practical standpoint, the laser offers distinct advantages over traditional chemical cleaning methods:

- ✦ **Selectivity:** The laser may be tuned to interact with specific substance.
- ✦ **Environmental Acceptability:** No dependence on hazardous chemicals or solvents.
- ✦ **Non-contact:** The process is amenable to automation and offers freedom from contact wear.
- ✦ **Preservation of Surface Relief:** Photons do not distinguish between peaks and valleys. The material and profile are preserved.

- ❖ **Versatility:** Optical flux intensities are achievable that can remove any material.
- ❖ **Localised Action:** The laser action cleans only where directed.
- ❖ **Controlled Removal:** A specific thickness of material can be removed.

These intriguing properties of lasers, coupled with recent reductions in size and costs of many commercial laser systems, has led to an increased interest in the potential benefits of laser technology to art conservation.

There is little evidence to begin assessing the long-term impact of laser cleaning, except on architectural stonework. Still, it is almost obvious that stone should be fairly resistant to the effects of lasers; after all, one seldom sees rapid deterioration of stone sculptures under the influence of light alone. Thus one would expect that any damage caused by a laser would be the result of secondary effects such as localised heating or plasma formation rather than by exposure to light. With careful control over the process, many of these secondary effects can be significantly moderated. But the potential of light to directly damage or alter other materials, especially organic materials, is well known. And while light damage is often seen in the immediate effects of bleaching, fading or yellowing of materials, the long-term effects, especially the breaking of chemical bonds, may not be easy to detect. Careful study of these factors is essential to build confidence in the feasibility of using lasers in art conservation.

Mechanism behind Cleaning of Stones by Lasers

The most common laser used in conservation at the moment is the Q-switched Nd-YAG laser, which provides short pulses (typically 5-10 ns long) of near infrared radiation at a wavelength of $1.064\text{ }\mu\text{m}$ (or $1.064 \times 10^{-6}\text{m}$). Their short pulse length prevents heat from being conducted beneath the soiling into the stone surface. The process of cleaning is self-limiting since once the dirt has been removed, further pulses will have no effect on the

surface as insufficient energy is absorbed to cause any damage. The Nd:YAG laser is also extremely reliable, easy to maintain, relatively compact and robust.

One of the commercial lasers cleaning systems available is with jointed articulated arm in which the beam emerges through a pen-like hand-piece within which a lens is used to produce a diverging beam. The Conservator controls the cleaning effect through adjustments to the energy in each pulse, the number of pulses fired per second (repetition rate) and the distance between the tool and the surface (which controls the intensity or spread of the beam). In another system, instead of articulated arm an optical fibre is used to deliver the beam.

Cleaning Parameters

The most important cleaning parameter is the energy density, or fluence of the laser beam, which is defined as the energy per unit area incident on the surface (energy per pulse/beam size at the surface) and is usually measured in joules per square centimetre (J/cm^2).

At low fluence ($< 1 \text{ J}/\text{cm}^2$), strong absorption of energy leads to rapid heating and subsequent expansion of a dirt particle. Since the pulse length is so short the expansion happens so quickly that the resultant forces generated are sufficient to eject the particle from the surface. This is a very selective process. If the fluence is increased slightly, then some material will be heated to a sufficiently high temperature to cause vapourisation. At higher fluences still (above approximately $1.5 \text{ J}/\text{cm}^2$; values depend on the properties of the soiling) the removal mechanisms become more complex and involve the formation of a plasma just above the surface and generation of a shock wave. This mechanism is less selective and can result in damage to the underlying substrate. Cleaning should therefore be carried out at the lowest practical fluence so that the most selective mechanisms operate.

Enhancement of Cleaning by Water Coating

Water can sometimes be used to enhance the cleaning effect. By brushing or spraying a thin coating of water onto the dirt surface immediately prior to irradiation, stubborn deposits of dirt can be removed without having to increase the fluence to unacceptably high levels. Dirt particles become coated with a thin film of water, which is also able to penetrate into cracks and pores within the dirt layer. Absorption of the laser beam by the dirt layer occurs as normal and rapid heating at the dirt/water interface leads to explosive vapourisation of the water molecules, which exerts forces on and within the dirt layer sufficient to eject further material from the surface. The addition of water usually increases the cleaning rate significantly.

Some of the Disadvantages of Laser Based Cleaning

Laser cleaning does not work on everything. The cleaning of polychrome sculpture poses problems since different pigments absorb different amounts of radiation, certain types being very sensitive. For example, a single low-energy pulse will be sufficient to turn vermillion from red to black. In cases where there is evidence of pigment on a stone surface cleaning is usually carried out in such a way that the area is not exposed to laser radiation, unless it is known to be stable at the fluence being used.

Although laser cleaning of sculpture is usually much quicker than cleaning by the more sensitive conventional techniques, the large scale laser-cleaning of buildings cannot, at the moment, compete in terms of speed with techniques such as grit-blasting. It does however leave the stone surface intact.

The relatively high initial cost of purchasing a laser system is seen by some as a disadvantage. This should be set against the low cost of maintenance and the savings that are made on time taken to complete a job. The development of laser systems is so rapid that it might not be too long before large-scale laser cleaning systems become available. Purchasing a laser cleaning system is a

long-term investment. In the short term it might make more sense to hire an appropriate system for a particular job.

Recent Developments

Ultra violet laser ablation is the result of the combined action of thermal, photochemical and mechanical processes. The laser light vaporises a black crust but does not damage the underlying stone because it is almost completely reflected. When the laser is used in the Q-switched operation mode, with very short and intense pulses, it is necessary to take into account effects such as blocking of the laser light by the dust plume and the mechanical effects generated by the expanding plasma and the rapid heating of the target material. In the UV laser ablation photochemical effects also have to be considered. In this case energetic UV photons are able to break molecular bonds in the target material. Thickness of the layer removed is very small when UV lasers are used. Hence researchers are concentrating in the use of UV lasers to stone cleaning. The main problem of using laser ablation technique lies in the discoloration of the material beneath the layer removed and the long-term effects subsequent to laser action.

Conclusions

In a country like India, which houses a variety of precious sculptures and monuments, implementation of laser cleaning can prove to be promising in preserving and conserving our assets. Lasers are being widely used in many industries and research laboratories. Recent joint venture of laser scientists and conservators is likely to yield fruitful results in the near future.

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Chemical Conservation of Sculptural Art in Stone in Rajasthan – Some Case Studies

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Rajasthan is surprisingly rich in sculptural art in stone. They do speak of a long history of art and architecture and also about their deterioration due to onslaughts, utter neglect and reckless renovation in subsequent times. The panoramic facades, bas-reliefs, carved-out sculptures of the monuments in the internal segments viz., vestibule, assembly hall and ceiling, usually create the fervour to look into them as excellent creation of the past. These are, in fact our cultural inheritance, which deserve to be preserved for posterity. Various methods were adopted for their preservation and restoration, as and when required even in earlier times. Several monuments in the world over are brought to nearly their original pride even after deplorable conditions caused due to human or natural calamities. Astonishingly, quite a good number of old and dilapidated architectural edifices studded with relief panels and of divinity or lovely damsels have been preserved in by-gone days by means of plastering and through layers of white wash. The monuments in remote areas, exposed to natural and manmade disasters, during ravages of time, have resulted at a greater length into their disintegration. The problem of the preservation of this theatre of history is intricate, complex and

involves chiefly (a) structural conservation and (b) chemical conservation.

The conservation and scientific treatment, incorporating physical and chemical methods after assessing the extent of deterioration and their true causes is, thus, the greatest need of the day so that historical heritage can be saved for times to come.

This article deals with some case studies of chemical conservation of sculptural art in stone belonging to the Government Museums of Rajasthan State situated at Jodhpur, Sîsar, Hawa Mahal and Amber (Jaipur). It also includes 'chemical conservation of fine carvings and bas-reliefs in a group of temples of early historic period in Osian District, Jodhpur and Nakîr Mata Temple in Ju Bhawanipura District, Jaipur.

General Causes of Deterioration

The stones commonly used in monuments are mostly granite, sandstone, limestone, schist, marble, quartzite, basalt, laterite etc. Temples, forts, palaces, cenotaphs, mosques and havelas are generally embellished in stone with sculptures, floral motifs, carvings etc., and at times with painted walls as well. These are categorised as inorganic or of stable nature as they are less prone to be effected easily by handling or due to display. Constant exposure and neglect, however, naturally lead to various causes of decay. More so no single particular cause can be made responsible for the gradual dis-integration except neglect, mishandling or onslaughts - both human and natural. Besides natural factors such as rain, sun, humidity, dust etc., the materials used in the formation of these monuments are equally responsible and sometimes cause deterioration. They include poor quality of stone, use of improper adhesives, the rusty iron nails in joints and the like which, indeed, prove fatal and reduce the life of the monument and so also its art. The effect of rain and moisture not only to the wall entablature but to the entire building results into the natural growth of moss, lichen, algae and vegetation

leading to the disfigurement and these are commonly termed as bio-deterioration.

Impregnation of salts in contact of humid air in the porous veins of the stone also result into the efflorescence of salts, splitting of the stone into separate layers and chipping off into pieces. Atmospheric gases like oxides of carbon, sulphur, nitrogen etc., are indeed, found harmful in contact with moisture and sweeping wind. These cause weathering in the form of hard crusts of gypsum on the surface popularly known as stone cancer. Excessive heat results into de-hydration and contraction in the constitution of the stone with the result the joints are widened. Some soft stones are susceptible to thermal expansion and show caking on account of it. Accumulated dust particles from the suspended particulate matter are absorbed in the pores of the exposed monuments turning it into yellowish colour with brown stains. Soot and smoke, emerging out of burning of the oil or fuel, is found in most of the old edifices in the form of a hard layer on the surface of the built heritage making it black, ugly and fast in look.

For reason of taste, ignorance or expediency of the people or the owners, the art and architecture of the sculptural art is found covered and blotted out by a layer of some opaque wash of lime or oil paint, in plaster beneath. Thus the monument abandoned for a long time to unfavourable climatic conditions are, in general, prone to decay and deterioration. Their treatment is often fraught with difficulty.

Methods of Chemical Conservation

In case of the dilapidated condition of any built heritage such as temple, fort or palace, conservation involves structural repair as well as chemical treatment. It is advisable to provide first protective measures such as strengthening of the basement, repair of joints of the various architectural members, attending to the leakage in the roof, maintenance of sun shades, improvement of

drainage system for disposal of rain water and the like. The plastering on the exterior of the building unknowingly proves beneficial as they are meaningful protection against rain and heat. Various kinds of screens also work effectively as measures of protection.

For eradication of lichens, algae and moss etc., the scientific treatment consists in scrubbing the affected surface using dilute ammonia solution. The cleaned surface is then impregnated with 1-2% aqueous zinc silico fluoride. This treatment of fungicide is repeated after an interval of about a week. Finally the porous surface is provided with a protective coating of poly vinyl acetate or polymethyl methacrylate. When plants and trees are found growing on the monuments, deep roots are cut off and the stumps injected by means of a syringe with sodium arsenite solution or sulphuric acid or tree-killer.

Organic growth may be removed economically by means of brushing off the stone with a 2% solution of zinc silico fluoride or alternatively by solution of zinc or magnesium chloride. A hard layer of old algae is best treated, at first, with formalin vapours, which facilitates the removal of desiccated tissues.

Certain kinds of stains seem to defy all chemicals and can only be taken away by using a plastic stripping film. The process consists of the use and application of a viscous film of nitro-cellulose. Insoluble crusts of foreign material causing local damage to polished marble can also be removed by means of scraping with a scalpel or riffler file followed by judicious polishing with suitable stone or powder. The removal of insoluble incrustation depends on their chemical composition. Acids decompose carbonates. The greatest care must be taken to localise the action of the reagent used in such a manner so as to soften the incrustation followed by mechanical crasing. The area should then be immediately washed with water. Hydrofluoric acid has advantage in its application, as it does not leave any damage caused by salt after impregnation as compared to hydrochloric,

citric or oxalic acids. Incrustations of calcium sulphate or gypsum have the tendency to be dissolved slowly in water. It is generally a more effective method of treatment to decompose incrustations by desiccating with an electrically heated spatula and further erasing it mechanically.

Fragments of stone are joined by using the polyesters or epoxy resins as they are more resistant to heavy material. Excellent kind of cement can be prepared out by the mixture of sand, powdered stone and polyester or epoxy resin. It helps in adjusting the ingredients of the stone. In case of wider joints and cavities, which is causing disfigurement or weakening of the surface, filling is done with mortar prepared from lime, stone powder or plaster of Paris mixed with *fenal*.

Chemical Conservation of Stone Sculptures

Almost every museum has a good repository of stone sculptures. The Department of Archaeology and Museums, Rajasthan, has a collection of about 7000 sculptures of various kind, acquired in its 20 museums and 2 galleries all over Rajasthan. Out of them about one third objects are on display while two thirds are kept in the reserve. In order to fulfill the requirement of establishing of a new gallery or at the time of an exhibition, objects, related to either the region where the new museum or gallery is to be opened or thematic display in an exhibition, are selected and brought at the site. During the last decade, quite a few deliberations have been made where the necessity of chemical conservation of such exhibits was found with foremost significance and yielded a good show.

The Archaeological Gallery at Virod Nagar, Museum at Sikar, Art Gallery in Amber Palace and an exhibition in Jawahar Kala Kendra and Government Central Museum, Jaipur are considered significant. While the art connoisseurs and museum experts highlight these manifestations in the light of magnificent art treasure and these master pieces in their aesthetic glory and

chronology, the chemists and conservators accomplish the duty to preserve this art treasure for the posterity by providing conservation treatment.

These works of art have a long history of their preservation. These are recovered either from exploration, excavation or as reminiscent from ancient temple sites. Ravages of time have great role in making their look blemished and gloomy by encrustations like lime and algal deposits, smoke and soot layers, *nikar* and paint, oil, dust and water marks. Exposed and isolated objects show symptoms of salt efflorescence, discolouration, stone cancer (deposits of thick gypsum crust), erosion effect, chipping off and splitting into layers by layers etc. These require conservation treatment involving cleaning and consolidation. First-aid measures in chemical conservation of such objects selected for a new gallery or an exhibition is considered to be urgent and foremost important.

Exhibits in museums are usually displayed on the pedestals made of wood or cement. These are exposed to temperature variation, light, human activities like touching, engraving, birds excreta, dust, dirt, dampness and water percolation during rains. These require periodic cleaning. Stains of whitewash or enamel paint are sometimes observed on the displayed exhibits probably due to negligency by the workers who are engaged to paint wall, doors, windows and pedestals. Elaborate crusting of such stains is done by washing with aqueous detergent or non aqueous solvents.

A marble sculpture is easier to be cleaned with a paste of *benzoate* or jelly of sodium salt of carboxy methyl cellulose (CMC) containing a 5% ammonia and *Lakshme*. Shining of edges or chipping off can be given uniformity by applying a thin coat of epoxy resin. A composite stone sculpture of *Hanar*, *Pramab* (Brahma) and *Martanda* (Sun) belonging to Government Museum, *Sikar* was badly affected with dust, dirt, *nikar*, oily accretions and hard deposits of lime. Deposits of lime were removed mechanically. For removal of dust, dirt, oily accretions and *nikar*,

a solution containing 5 ml of liquor ammoniac, 5 ml *Labolite* and 5 gms of sodium salt of carboxy methyl cellulose in 1000 ml of water was used. After thorough washing with water, a preservative coating of 3% poly vinyl acetate in toluene was given to protect it for posterity.

Yet another sculpture of *Mahabharati* (*Matika*) belonging to Government Museum, Jodhpur (find place-Devangan) was covered with a thick layer of lime and gypsum deposit. Hard deposits of lime were cleared by mechanical means using various tools. Then the sculpture was given chemical treatment with a solution of 5% *Labolite* and 5% liquor ammoniac in water to clean it. Finally, it was given a preservative coating of 3% poly vinyl acetate in toluene.

It is noteworthy that there is no one factor, which may be made responsible for the deterioration of these exhibits, hence, there is always need for a group of chemicals for conservation treatment. To prevent the exhibits from deteriorations, which have detrimental effect of their disintegration, first-aid measures are necessary. Stores should be made free from dust, dirt, humidity and air pollution. Exhibits should be covered with polythene sheets in stores. Small objects should be displayed within glass showcases.

Chemical Conservation of Nakti Mata Temple

Nakti Mata temple is situated in the village *Jai Bhawarpura*, at a distance of 22 Kms from Jaipur city. This temple was built in 9th Century A.D. during the regime of the Pratihar in North India. The temple is declared protected monument of the Department of Archaeology and Museums, Rajasthan, Jaipur by notification under Rajasthan Monuments, Archaeological Sites and Antiquities Act, 1961. The red sandstone structure of this temple resembles characteristically with the temples at Jodhpur Ocean district and at Barmer, Kutch district in Rajasthan.

The *Jagat* of the temple stands about 3.4 meters high from the ground level. The stones of the platform were found broken and lying scattered around it. The temple was found in a disapidated state due to weathering, rain, neglect and human and animal vandalism.

Due to these reasons, this temple required to undertake structural and chemical conservation. The temple had following parts to be attended for chemical conservation work :

1. Podium (lower level)
2. Sanctum sanctorum with a poeth.
3. Spire door jamb, pillars, lintels.

The surface area to undertake chemical conservation work was about 110 sq. metres.

Conservation Status



Stone Sculpture Before Chemical Treatment

However, signs of some deformation in its structure are visible. The hollowness inside the brick structure has made a thorough passage for percolation of rainwater in side the temple. The upper section of the spire is broken and displaced from its original

Nakti Matr Temple was built more than 1000 years ago. From close examination, it seems that some conservation works had been done earlier using plain stones in the gaps. Brick structure erected as support for this temple has helped to prevent it from extensive damage in its fabrics.



Stone Sculpture After Chemical Treatment

place. One of the pillars in antural is found broken and replaced by a plain stone at the height where keechak is missing. A portion of the front part is also restored by uncarved stones. Some holes and gaps in one corner of antural are resulted due to water erosion. Some tilting effect is visible at the joint of lintel and pillar in the antural due to development of gaps. Since the temple is under worship, but it was being ignored and victimised with the result portions like porch, steps and platform were found missing. Most of the exquisite carvings in the relief work of antural were damaged.

Inner walls of *Garbha-grha* were found completely darkened with deposits of smoke and soot. A black sculpture of *Kali Mata* has been installed inside on a platform at half-meter height. Devotees had coated *anar*, oil, milk, etc.; on various parts of the deity. Different parts of sanctum-sanctorum like door-punch, lintel, pillar, ceiling etc., are also found thickly coated with oil, dust, lime, smoke and salts. These incrustations have obliterated the entire carving. Exposed portions viz., spire and sancum-outer are affected with run water. Vegetational and algal growth along with lime deposits are the main causes of deterioration.

Trends of Chemical Conservation

Before starting the work of chemical conservation, full photo documentation on its state of conservation was made. The following problems of chemical conservation treatment were attended:

Cleaning of

- (i) Deposits of algae, moss and lichen
- (ii) Deposits of lime, gypsum and whitewash
- (iii) Deposits of smoke and soot
- (iv) Vegetational growth
- (v) Deposits of oily secretions, *anar* etc.
- (vi) Dust, dirt and water marks

Protection against

- (i) Micro-organisms
- (ii) Atmospheric pollution, rain etc.

Restoration of

- (i) Joining parts
- (ii) Filling of gaps

Technique of Chemical Treatment

- (i) For the removal of smoke and soot, use of a solution containing 5 ml. of *Labolite*, 5 ml. of liquor ammonia and 5 gms of sodium salt of carboxy methyl cellulose in 500 ml. water was made. This solution was applied 2-3 times with soft hairbrush and washed out each time with the help of water after brushing with nylon brush thoroughly.
- (ii) Use of a solution containing 5 gms of sodium bicarbonate, 5 gms of ammonium bicarbonate and 5 gms of sodium carboxy methyl cellulose in 500 ml. of water was made as above for better results.
- (iii) For removal of algal growth in the exposed portions, use of a solution containing 5 ml. of *Labolite*, 5 ml. of liquor ammonia and 5 gms of sodium carboxy methyl cellulose in 500 ml. of water was made. The solution was applied on the affected area and then covered with tissue paper. After 3 hours, the surface was cleaned with water using a brass wire brush.
- (iv) Hard incrustations of lime and gypsum were removed by mechanical means, using various tools.
- (v) One percent zinc silico fluoride was used for prevention of algal and moss growth.
- (vi) Use of 3% poly vinyl acetate in solvent was made as surface preservative against weathering effect.
- (vii) Powdered stone mixed with poly vinyl acetate emulsion was used for filling up the small gaps.

(vii) Epoxy resin mixed with stone powder was used for joining some of the broken stones.

Chemical Conservation of a Group of Temples at Osian

A group of temples at Osian generally belonging from 8th - 10th Century A.D. were declared protected monuments by the Department of Archaeology and Museums, Rajasthan, Jaipur and henceforth, management of their conservation and development remained in the purview of this Department. The monuments are neglected and exposed to the natural and man-made disasters during ravages of time thereby resulting in disintegration. The problem of preservation of these edifices of historical importance is intricate, complex and involves chiefly (a) structural and (b) chemical conservation. Here, a report on chemical conservation of a group of temples at Osian (Jodhpur) is described.

Conservation Status

There are a dozen of ancient temples in 4 Kms area of the town, Osian (ancient name *Udan*), 65 Kms away from Jodhpur on way to *Jaisalmer* (via-Phalodis). Out of these



*Naradevi, 11th Century A.D.
Before Conservation*



*Naradevi, 11th Century A.D.
After Conservation*

temples, *Mahaveer Jain* temple and *Sardhya Mata* temple are living temples, which are under worship. Therefore, they are constantly maintained with regard to their cleanliness and also to the repairs of broken and dilapidated architectural

parts. Other temples viz. *Haridwar* temple, *Sun* temple, *Piplad Mata* temple, *Vishnu* temple and *Jhar* temple were found to stand uncared so far.

All these temples are significant examples of sculptural and architectural treasure of art constructed during the early medieval period. Red sandstones, used in the construction of these temples, have become dirty and blighted due to accumulation of tarry material from weathering and dusty winds common in summer. Exposed relief panels of the porch and assembly hall are darkened owing to the deposits of algal and lichen growth. Hard incrustations of soluble and insoluble salts were noticed on the portal of the sanctum obliterating details of the embedded sculpture. Only dust is accumulated along with smoke caused through burning of lamps. This deposit was hardened as a result of interaction with water during its seepage through ceiling. While in constant neglect, the epidermis of the exposed stone is eroded and sedimented with salt incrustations and hardened as stone. Hard incrustations of lime are a big problem for conservation treatment.

Conservation Treatment

There is a large scope for chemical conservation in each one of the temples at Orian. *Haridwar* temples, *Sun* temple, *Vishnu* temple and *Piplad Mata* temple were considered to be attended for treatment in two phases as these were showing signs of extensive deterioration. Deposits of lime, algal growth, oily soot and smoke were main causes of their decay. Chemical conservation of these temples involves use of chemicals, tools and man power. The treatment of affected portions viz. *door-pand*, pillars, lintels, vestibules, ceilings, roofs was done as follows:

- (i) Surface dust and dirt were removed by washing with a spray of water followed by brushing with nylon brushes
- (ii) Mechanical method of using pointed and sharp tools like spatula, variegated knife, steel pins, screw driver, scalpel etc.,

helped in removal of thick deposits of lime inside the carved portions. Nonetheless it was necessary to let them swelling and loosening with the help of water and aqueous solution of different chemicals.

- (iii) Dark and green patches of algal growth were removed by treatment with a 3% aqueous solution of *Lalohat*, liquor ammonis and sodium salt of carboxy methyl cellulose. This solution was applied 2-3 times and then allowed to remain covered with two sheets of tissue paper for a day by moustering intermittently. Hard tooth brush, brass wire brush and hair brush were used while washing with water till all the salts and unused chemicals were cleaned.
- (iv) Hard incrustations were locally treated with a solution containing 1% hydrofluoric acid, 5% sodium salt of carboxy methyl cellulose in water. Alternatively, a 5% hydrofluoric acid neutralised with 5% sodium hydroxide in water was used locally to clean calcareous deposits.

Use of strong chemicals for cleaning the affected portions was made cautiously as these dissolve and decrease their binding forces. Neutralisation as well as thorough washing of unused chemicals, paper pulp or poultice of inert material moustened with water was applied to prevent the stone from side effects of the chemicals. Mechanically scraping of loose deposits help in the cleaning treatment.

- (v) A 1% zinc silico fluoride or polycide was applied to prevent growth of macro-organisms, which otherwise show rapid regeneration even after cleaning treatment is done.
- (vi) A 3% poly vinyl acetate in toluene or a 10% silicone solution was applied for prevention of rapid salt effect.

Conclusions

Preventive measures are more useful than curative measures. Use of excessive chemicals should be possibly restricted as they react with the matrix of the object and result in abrasion, salt effect,

effluorescence and intensify cracks, porosity and erase out the surface details, sheath or epidermis i.e. loss of certain materials from its constituent.

It is necessary to keep in mind that whatever is the conservation treatment adopted, it will last only for a protracted period. The only way to prolong the life of the monument is to ensure regular inspections (once a year) and appropriate maintenance as soon as new damage is detected. Even if such activities are expensive, timely and regular maintenance is the only successful strategy of conservation.

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Restoration of a Rare Nagini Sculpture and Its Transportation to U.S.A.

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Nagini, a rare and life size sculpture made in spotted sand stone, belongs to pre-Kushan period, 1st Century A.D., originally from the place *Nandia* near Mathura in U.P. and is at present in the collection of the National Museum, New Delhi.

The sculpture of *Nagini* is one of the very rare objects. There are only 3 *Naginis* from pre-Kushan period in the world, one is with Tokyo Museum, Tokyo, Japan another is with Nelson Atkins Museum of Art, U.S.A. Kansas city and the third is with National Museum, New Delhi, India. All the three *Naginis* belong to the same place, are made up of same material i.e. sandstone and apart from these similarities, they are even damaged from the same portion.

This *Nagini* was requested on loan by the Nelson Atkins Museum of Art, Kansas city, U.S.A. for its incorporation in the exhibition accompanying the "symposium" on the Cusp of an Era: Art in the Kushan World", which was inboard for Rs. 1 crore.

The sculpture at that time was kept on storage in the National Museum, New Delhi leaning against the wall, both for the security reasons and due to damaged wooden base.

The sculpture was broken into two pieces, which were held together by their own weight and by a wooden support in the back fixed by an iron clip. In this position, it was considered that the object was not fit to be sent abroad for exhibition. A team of conservators and photographers from Nelson Atkins Museum of Art, U.S.A. visited the National Museum, New Delhi

to examine the condition and status of the sculpture. They sent a report in which they had suggested to construct a mount for the *Nagai* at the exhibition venue, which did not involve the use of any permanent attachments or additional pinning. Further, the use of any vertical pins between the main fragments were not advisable, as the stone was inherently less strong in this direction.

Examination

Upon the repeated request, the sculpture was examined in detail to assess its condition and state of repair and status report was prepared by conservators of the National Museum Laboratory (NML). The sculpture was found broken as to two major fragments with a complex shape at the waist, which were placed perfect over each other and held together by their own weight without the use of any dowel or adhesive.

The window in the rear of the base afforded a limited view of the ankle fracture. From this, it was clear that the sculpture extended only a couple of inches beneath the upper surface to the base and had no permanent attachment. The sculpture was not capable of standing on its own.

Ancient losses existed due to abrasion between bedding places in areas of the belly, face of breasts, small fragments from the wrist and rear of the waist break are missing. The broken surface of



Upper Port of Nagai Sculpture

the sculpture are covered with calcareous accretion of a light buff colour and coloured spots were also visible.

Two fragments from adjacent to the cut in the right breast had been reattached.

Restoration

The two pieces of the sculpture were joined together by drilling 6 inches deep hole in the upper torso and 8 inches deep hole in the lower portion in such a way that the two holes corresponded perfectly with their axis. This was done with utmost precautions, as this stone is sedimentary in nature and inherently weak.

A single stainless steel dowel of the size 14 inches \times $\frac{1}{2}$ inches was purposely made rough. Epoxy resin (*Araldite*) was used for fixing the dowel as well as the two pieces together. A mixture of sandstone powder and *Araldite* was used for filling and further strengthening the gaps between and around the two joints.

Besides this, the minor surface fracture on the right breast and on the left side drapery had been consolidated.



Lower Part of Nagan with a Dowel

The slashes of white and colour had been removed.

Calcareous secretions of buff colour were allowed to remain, as they are the evidence of the sculpture's burial history as well as they seemed to strengthen the surface.

Packing

The responsibility of packing and transportation was assigned to Star Worldwide Movers by Nehru Arts Museum of Art under the supervision of the Conservators of the National Museum Central Conservation Laboratory, New Delhi.

To ensure the safety of the sculpture, keeping in view of its size, weight, fragility and importance, the National Museum

Laboratory decided to get the object packed by Double Crate Method as utmost precaution was to be taken, while handling, packing and transportation of the object.

The wooden base of the sculpture was removed after resting it against the wooden panel of 2 inch thickness, which was padded with the cushioning material (super foam), proportionate to the thickness of the sculpture and held at an angle. Then together with the wooden plank the sculpture was placed in the horizontal



After Restoration

orientation. This assembly was further covered with wooden board on all sides to form a base and was filled with cushioning materials like foam and thermocool to prevent the movement of the sculpture during transit. This box was finally covered with wooden board.

This box was then encased in an outer box with cushioning materials filled in between. The inner box was given the necessary provision to facilitate its lifting.

This kind of packing effectively protected the sculpture from movement and externally transmitted shocks and vibration.

Transportation

The packed object was then loaded on truck for airport transport at New Delhi by Star Worldwide Movers (SWM) under the supervision of the Conservators of the National Museum Laboratory. The box was tied up with a rope to resist movement.

In the presence of Conservator, Mr. C. B. Gupta, from the National Museum Laboratory and a representative of Star Worldwide Movers, the object was embraced in horizontal orientation on the Paris bound flight.

The object was disembarked at Paris and again embarked on the Chicago bound flight under the vigilance of Star Worldwide Movers and Mr. C. B. Gupta.

At the Chicago Airport, the object was disembarked from the aircraft and placed on the truck to reach its destination, Kansas city. The truck was having metal supports on both the sides with grooves. To resist the movement of the assembly, that is, the sculpture with its packing, the metal rods were fixed in the grooves along the length and height of the packing.

Display

Upon reaching the Nelson Atkins Museum of Art, the object was unloaded by the use of a lift and placed in the security room for a day for cooling.

On the second day, the packing was opened and the object was inspected to study its condition. The sculpture was found to be perfectly intact as it was before being packed.

"Nages" was displayed on the metallic pedestal made up of stainless steel. Since the feet of the sculpture were musing, it was not capable of standing on its own. It was made to stand over the pedestal made of plastic resin of putty like consistency, which upon drying conformed to the shape of the break. Resin was hardened to form a support with no direct bond or contact with the stone object.

The sculpture was supported at the back by a steel rod screwed to the pedestal and under the breast by a metallic rod to prevent any occurrences of abrasion.

Conservation of Monuments

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Our cultural heritage is the best and most valuable treasure to us. As such it is the first and foremost duty of every Indian citizen to protect and preserve it, so as to pass on the same to the generations to come. The monuments are standing testimony of our age-old tradition, art and archaeology. Hence, the Archaeological Survey of India, which is a body of the Government of India is taking care of the monuments of national importance.

What is a Monument?

A structure, which is not less than one hundred years old, is called as a monument. In our country monuments are being taken care of by various agencies such as private, hereditary trustees, State and Central Governments. It can be classified as A, B, C & D based on the importance of the monument in question. Apart from the age, the structure can be classified by its art, architecture, epigraphy and stylistic features etc. If a monument is rare of its kind and of national importance, such ancient structures are declared as monument of national importance by 1958 Act, and being looked after by the Archaeological Survey of India. As on date, there are 17 circles and two mini circles functioning throughout the country under the Archaeological Survey of India for conserving/preserving around 5000 monuments/ ancient sites.

What Are the Principles of Conservation?

The word conservation is not merely indicating only structural repairs, but imply upon the archaeological principles on this

subject, which are quoted in the Archaeological Works Code. Hence the conservation means volume of principles to be adopted while executing the conservation work. Conservation of a structure can be of two types, structural and chemical. What is structural conservation? As stated earlier, the conservation of monument means treating the structure in question after having made a thorough study of the same. The Conservator has to understand properly the existing problems as well as its remedy too, before laying his hands on that. Otherwise, it is impossible to preserve any ancient structure, despite of all expertise and availability of the men and material. Hence the Conservator needs an expert's guidance.

How to Conserve?

The Conservator has to approach his task in a systematic way, by understanding the following facts:

He has to study and know the type of monument, whether it belongs to *radha* (made out of one core material, example stone) or *maru* (combination of stone and brick as core material) or *ankharna* (using more than one materials as core). For example a rock-cut cave temple as *Pallava/Pandya*, where only one material exists as core i.e. stone. If one takes a *Chola/ Vijayanagara* structures wherein one does find stone and brick as core materials. Similarly for example of the third variety, one can cite Fort Saint George, Chennai wherein stone and brick and wood are used as core materials. Hence, the Conservator has to pay his first and foremost attention to classify the type of the monument, which he is going to conserve. Then comes its age and method of construction. In other words, the Conservator should know how the builder originally built it. Unless he is aware of this fact, it is not possible for him to choose the correct method of conservation.

What Are the Works to be Carried Out before Conservation?

Though the conservation is the ultimate aim of the Conservator, he has to carry out some other minor, but important works before he touches the structure. The monument, which is going to be conserved should be documented in all respect, such as photographic recording from various angles especially the fallen portion, out of plumb area, vertical or horizontal cracks and missing members etc., are to be recorded properly. In addition to this, all members (stones) are to be numbered with cardinal indication, row and stone numbers etc., before dismantling of the dilapidated structure. If it is not done or over looked by the Conservator, he cannot restore that monument as it was before. Therefore, in the conservation of ancient structures, it is not only the service of the mason or *stapari* is required, but also the services of photographer, modeller, markman and surveyor etc., are required before commencing actual work.

Once the problems are understood and salvation method or approach is finalised, the Conservator should look further deep and find out the combination of the building materials, which were used in the past. This is inevitable aspect to prepare similar combination of materials, so that the structure will not loose its colour and character etc., which are very important in archaeological conservation. In India, only preservation is accepted and allowed, but not restoration or total reconstruction of any monument. However, partial restoration or underpinning is permitted to safe-guard the parts of the fabric. On this line, Sir John Marshall issued a conservation manual first in 1907 and again in 1924.

Identification of Enemies of Monument

The first and foremost enemy is the human agency whose religious bigotry of one community often leads to the disfiguring of monuments of their rivals. Similarly age, negligence, vegetation, rainwater, sub-soil water, salt laden air, smoke etc., are noteworthy

to mention. Hence, the Conservator should give proper attention to study, understand and identify the real enemies of that monument. Otherwise, the structure cannot be brought to its original glory, even after doing necessary conservation.

Methods of Conservation

Alexander Cunningham started a systematic survey of ancient monuments in 1861. Some important monuments such as Taj (in 1808), *Panchajanya Jyoti* and *Likhandara* (in 1815), *Qutb* (in 1826), *Alauddinagar* (in 1867) and *Thatta* (in 1885) were conserved.

Vegetation and Its Removal

Owing to heavy rainfall, ancient monuments become the home of vegetation. Among these, the Indian pipal and banyan trees are in particular most destructive in nature. As the roots expand, disintegration is accelerated, resulting in easy penetration of rainwater and vegetation into the core thereby augmenting the substance upon which it thrives and looks like a hanging garden. Hence, the Conservator should cut the stems and pluck off the roots, then pour any corrosive acid or tree killer into the holes before plugging with mortar. If any lapse is there in the process, the very purpose of vegetation clearance will be defeated and plants and mushroom will grow over the monument immediately.

Raking out Joints – Filling and Pointing

While the wall or dome or any other structural surface has got cracks or voids that should be completely raked out to remove dirt and loose dead mortar. The area should be thoroughly washed with salt free water with the help of a hosepipe or garden – syringe. This will make the area clean and wet so that the pointing material will go into the voids or cracks and settle properly. The required liquid mortar has to be poured through an appropriate tool either in the form of liquid or solid till the cavity is completely filled. Besides this, a sunken pointing should be made with matching colour and texture of the old work.

Wall Tops and Rough Packing

Wall tops, which are exposed to the nature, should be waterproofed so as to prevent any percolation of water or moisture into the core of the wall. The upper coarse stones or bricks, which normally found loose, are to be refixed properly with combination mortar and joints should have sunken pointing. Similarly, when the core is exposed, such as broken wall-faces and wall tops need rough packing. This sort of conservation reproduces the originality of the existing core; at the same time the rough packing does not look obstructive.

Grouting

Grouting is a sort of treatment to fill up the voids and cavities. For this work, the liquid mortar is usually prepared with combination of sand and lime or sand and cement. This treatment can be made either manually or mechanically. Hand grouting suffices for small fractures and voids created while dismantling of the structure or removal of vegetation. While applying this method, the work should be executed from the top, so that no air pockets are formed. When this technique is adopted through a machine, it should be carried out on the gravitation-principle or under pressure, the latter process being taken recourse to, when the structure is of assured solidity. This type of grouting was successfully carried out to conserve the Qutub-Minar at Delhi in the recent past.

Temple Conservation

The conservation of an ancient temple looks very easy, but in fact it is very tough and challenging one, when the execution takes place. As stated earlier, all pre-requisite works such as documentation in all respects, survey, examination etc., are to be completed before the Conservator lays his hand on the monument. Once dismantling starts, the temple members are to be stacked properly and separately according to the division such as *adhishthana*, *prada*, *prastara* and *stupa* portion.

This will enable the Conservator to find out the missing stones for reconstruction. Following this principle, we have successfully conserved temples at *Velore*, *Nattory*, *Erakthampattu*, *Syamangalam* etc., in *Velore* and *Thiruvannamalai* districts.

Secular Building

In India, apart from temples, churches, mosques, *garabars* and other religious places, a number of secular buildings were also built through the centuries. During the colonial period also some outstanding secular buildings were built in all the metros and cities. One among them is the Old Connemara Library building inside the museum campus.

As per the tablet in the library building, it was declared open by His Excellency Sir Arthur Elbank Havlock on 5th December 1896. This unique building was built as a Public Library. Unfortunately, the Conservator while carrying out the earlier conservation did not properly understand the architectural intricacy. With a result, the reading gallery turned into a dark room, because all the glass tiles were replaced with ordinary *Mangalore* tiles.

This building has got a two-tier system of roof. The upper roof was covered with *Mangalore* tiles, whereas the lower roof was originally covered with imported glass tiles for allowing the daylight to the reading gallery (first floor) through the semi-domical wall, which is fixed with stained glasses. Unknowingly, glass tiles in the lower roof were replaced with *Mangalore* tiles as and when they got broken. This has prevented the daylight or natural light into the gallery.

This building has flanking lower Madras terrace roof although. Due to age, it was profoundly leaking. The symmetrical flood designs made of pure lime with brick *chajra* has got severe damage.

The Archaeological Survey of India, Chennai Circle, Chennai has taken up this monumental conservation work as a civil deposit work and currently the work is in progress.

Conclusions

In nutshell, I have outlined the principles of conservation, which are accepted and adopted by the Archaeological Survey of India. Hence, any Conservator who takes up the assignment of conservation of any ancient monument, should give due respect and thought to the points, which are discussed in this paper to achieve success in his mission.

Rehabilitation and Retrofit of Earthquake Damaged Monuments in Gujarat

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Earthquakes pose a serious threat to architectural heritage, predominantly composed of unreinforced masonry. Factors such as age and weathering of building materials, exposure to past seismic events and the inherent weakness of masonry in carrying tensile stresses amplify the vulnerability of masonry monuments to future seismic events. The 2001 Bhuj earthquake at Gujarat in India hit a region with a rich cultural heritage. The Bhuj earthquake of 1819 A.D. measuring close to 8 on the Richter scale was responsible for loss of numerous monuments; the Bhuj earthquake of 2001 A.D. has only been a continuation of the saga. Earthquakes are recurring features and it is relatively simple to assess the vulnerability of a particular region to seismic activity. Once the seismicity of a region is established, there are innumerable ways in which cultural property can be preserved. Worldwide there are as many as twenty anti-seismic strengthening and retrofitting measures that can be applied to masonry monuments. The latest advancements include smart materials like the Shape Memory Alloys for retrofitting monuments and the use of Base Isolation Technique to protect valuable monuments. Extensive use of computer modeling to analyse the structural behaviour of the building under various loading conditions is another field of immense contribution to Conservation Engineering, internationally.

Chemical Conservation of Sculptural Art in Stone in Rajasthan-Some Case Studies *-Shashi Prabha Saxena, Hachand and Jagdeepi*

Conservation of Monuments *-K. T. Narasimhan*



Nati Mata Temple, Jaisalmer before Chemical Conservation



Nati Mata Temple, Jaisalmer after Chemical Conservation



Front Manaps of Arman Khoro, Pushpanwarin Temple, Punalokh, Pudukkottai District before Structural



Front Manaps of Arman Khoro, Pushpanwarin Temple, Punalokh, Pudukkottai District after Structural Conservation



Conservation of Soudhasekharan Temple, Inuvharaha, Pudukkottai District before Structural Conservation



Conservation of Soudhasekharan Temple, Inuvharaha, Pudukkottai District after Structural Conservation

*Rehabilitation and Retrofit of Earthquake
Damaged Monuments in Gujarat*
-M.S. Mathew, Arun Menon and Sruja Chandran



Ahmed High School, Bhuj



Damaged Minaret of Adipat Kalish
Mosque (17th Century A.D.) Amrothind



Rao Lakha Chattri (18th Century A.D.),
Bhuj before Earthquake



Rao Lakha Chattri (18th Century A.D.),
Bhuj after Earthquake



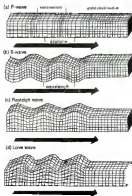
Parvati Damaged Rajpoot Chattri, Bhuj



Danti Tumba (17th Century A.D.)
Affected by Earthquake

Earthquakes, Their Causes, Ground Motion and Effects on Structures

Ground motion generated by sudden displacements within the earth's crust, resulting in shock waves that travel through the earth is called an earthquake. Earthquakes are caused by various natural phenomena such as tectonic processes, volcanic eruptions, sudden failure of parts of the ground, as well as by human activities such as large excavations in mines, explosions and large water reservoirs. They develop apparently as a result of elastic rebound of rocks when strain energy is suddenly released. The



Four types of seismic waves: (a) In P-waves particles oscillate to and fro along the direction of wave propagation; (b) In S-waves the particle motion is transverse; (c and d) Rayleigh and Love waves are surface waves.

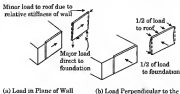
Rayleigh waves travel in a backward vertical ellipse motion, while Love waves travel transverse and horizontal. In both Rayleigh and Love waves, particle motion decreases with depth from the surface.

energy builds slowly in a fault zone until the stored stresses become greater than the rocks can withstand and then the earthquake occurs.

Two types of seismic waves are generated at the slippage zone. Since they propagate within the rock of the earth's crust, these two types of seismic waves are called body waves. The two types of the waves P-waves and S-waves as they propagate through the stratified formations of the earth's crust get transformed into surface waves. These surface waves propagate on the earth's surface in two-principal forms as L-waves (after Love) and R-waves (after Raleigh), which vibrate in an elliptical form in a plane perpendicular to the earth's surface. The seismic waves generated in the focus, propagate through different layers of rock and soil. On their way to the surface, they reflect and refract, and also change their amplitude and frequency of oscillation. The waves are filtered and amplified or attenuated when passing through various layers of rock and soil with different mechanical properties. When the seismic waves finally reach the surface and induce vibration to buildings, they reflect apart from the characteristics of the earthquake source and mechanism, the characteristics of the bedrock and soil on the path of propagation to the building site. These waves ultimately cause the devastation.

In the case of Gujarat, an earthquake of M_w 7.7 struck the Kutch region of Gujarat on the 26th January 2001 at 8:46 a.m. The epicentre of the earthquake was at 23.36°N and 70.34°E. The hypocenter depth was between 17 to 22 km on a fault plane that strikes about N40° E and dips 60° to 70°. Strong ground motion lasted about 85 seconds and lower level shaking lasted several minutes. The closest ground motion recordings are from Ahmedabad, where peak ground acceleration was 0.11g.

The response of a structure to earthquake loading is dictated by the dead weight of the structure, its fundamental period of vibration and its efficiency of energy absorption. The dead weight of the structure has a direct bearing on the force effect caused



by motion. The period of vibration of the structure is determined by its mass, stiffness and size; the energy absorption efficiency depends on the elasticity of the structure, stiffness of supports, number of independently moving parts, rigidity of connections, etc. During an earthquake, there is random motion of the ground surface generating lateral forces, which has the most damaging effects on a stationary structure primarily designed to carry gravity loads acting vertically downwards. The horizontal drift or deflection of the structure, which is a structural deformation is a means of partial dissipation of energy of the seismic force acting and is favourable to the structure up to a certain extent. Excessive drift may be objectionable to building occupants and could cause damage to components of the building. In a lateral resistant system, the components first exposed to horizontal forces are the spanning elements of the roof and floor system. Lateral forces collected by the horizontal spanning elements transfer the load on to the vertical bearing elements, mainly walls, and finally the vertical bearing system in turn transfers the load to the foundation system. Solid walls have varying stiffness in different directions depending on the direction of the lateral load acting on its surface. Walls are relatively flexible perpendicular to their plane and quite stiff in their own plane.

Lateral forces acting in the plane of the wall cause diagonal shear cracking and the classical 'x-cracking' observed in masonry

structures is a result of repeated and reversed action of lateral forces in the plane of the wall. The 'x-cracking' is seen normally in wall panels between two floors and two openings. Out-of-plane bending is induced when lateral forces act perpendicular to the plane of the wall panel whose boundaries are restrained. When the stresses exceed the internal resistance of the material of the structure, the wall plane fails either by propagation of cracks or 'pushing out' of the critically stressed parts. In cases where the boundaries of the wall are not restrained, out-of-plane-flexure may produce larger damage or even collapse. High seismic actions can cause local damages, permanent deformations or even complete detachment of the facade from the adjoining wall.

Damage to Monuments in Gujarat

Gujarat has a large number of historical monuments spread across its vast landmass. During the earthquakes almost 90% of heritage buildings in Gujarat State were affected in some form or the other, especially in Kutch district. A number of national monuments, under the jurisdiction of the Archaeological Survey of India in the Ahmedabad region, suffered moderate to extensive damage. The State Archaeological Department lost a number of its monuments dating back to the 9th and 10th Century spread over the Kutch district. The principal author had undertaken an extensive survey of quake-affected regions and studied 28 monuments damaged by earthquake in Ahmedabad, Patan and Kutch. The architectural heritage of Gujarat presents a rich blend of Hindu, Jain and Islamic building traditions with the indigenous art of woodcarving. The minarets of the mosques of Gujarat and its step walls are unique structures. Most of these monuments are made of sandstone from quarries of Dhargolbru in Gujarat. The minarets of Gujarat, victims of several earlier earthquake events are a diminishing heritage. The minarets of *Shah Alam's* *Raaga*, *Acharya Keki's* mosque and *Bilgi Masjid* have come a cropper this time. A number of 15th and 16th Centuries A.D. structures, the Mausoleum of Syed Usman, *Luxer Mosque*,

Sarkisij group of monuments and Bhadra fort are some of the other monuments damaged. Kutch has lost a number of its 9th and 10th Centuries A.D. structures like the Jain temple and *Jarya Mandir* at Kanthkot, and *Rav Lakha Chotr* at Bhuj 19th Century A.D. A typology of damage for typical structures has been arrived at, depicting all the possible damage and collapse mechanisms. Based on the European Macro Seismic Scale, a damage chart for a typical monumental structure in Gujarat has been developed as presented below:

1. Name of the Monument: *Jami Masjid* at Ahmedabad

Grade of Damage: 1

Nature of Damage: Widening of joints in the domes, 2 Damage to stone traceries in wall openings.

Reason for Damage:

1. Excessive lateral displacement of supports during ground motion, 2. Excessive out of plane bending.

Suggested Repair Measures:

1. Grouting of widened joints with combination mortar and strengthening of plane shear and out-of-plane bending of tracery panel corbelled dome with intrados reinforcement of FRP tendons to improve flexural behaviour.
2. After repointing of joints, steps of FRP laminates at the joints on either sides.

2. Name of the Monument: *Abmed Shah's Masjid*, Ahmedabad

Grade of Damage: 1

Nature of Damage: Falling off of merlon and cornice stones in the front facade

Reason for Damage: Excessive vibration of these elements as cantilevers and toppling due to lack of positive connection or fixity.

Suggested Repair Measures

Insertion of stainless steel rods, 7.5 cm into the supporting base and one-thirds into the above. Rods can be embedded in cement mortar

3. Name of the Monument: *Achyat Kabe's Mosque*, Ahmedabad

Grade of Damage: 4

Nature of Damage: Partial collapse of a minaret.

Reason for Damage: Excessive vibration of vertical cantilevers in bending and torsional mode.

Suggested Repair Measures

1. Reconstruction of the damaged segments with cement mortar in the joints.
2. Circular prestressing with steel or FRP tendons at close intervals.
3. Vertical prestressing with steel cables and rock anchors.
4. Suitable strengthening of openings

4. Name of the Monument: *Sidi Jaffer Mosque*, Ahmedabad

Grade of Damage: 3

Nature of Damage: Widened joints of stone tracery panels

Reason for Damage: Excessive out of plane bending

Suggested Repair Measures: After repointing of joints, strips of FRP laminates at the joints on either sides.

5. Name of the Monument: *Sidi Barber's Mosque*, Ahmedabad

Grade of Damage:

Nature of Damage: Dangerous vertical cracks and widened joints on the minar,

Surface cracks and flaking of central shaft of spiral staircase of minar

Reason for Damage: Excessive vibration of the cantilevers in bending and torsional modes.

Suggested Repair Measures

1. Reconstruction of the damaged segments with cement mortar in the joints.
2. Circular prestressing with steel or FRP tendons at close intervals.
3. Vertical prestressing with steel cables and rock anchors.
4. Suitable strengthening of openings.

6. Name of the Monument: *Shah Alam's Mosque*, Ahmedabad

Grade of Damage: 5

Nature of Damage: Total collapse of 4 pillared pavilion. Collapse of two storeys of minaret.

Reason for Damage

Excessive lateral displacement and poor diaphragm action by the structure as a whole.

Excessive vibration of vertical cantilevers in bending and torsional mode.

Suggested Repair Measures

1. Archaeological reconstruction with the application of anti-seismic measures.
2. Reconstruction of the damaged segments with cement mortar in the joints.
3. Circular prestressing with steel or FRP tendons at close intervals.
4. Vertical prestressing with steel cables and rock anchors. Suitable strengthening of openings.

7. Name of the Monument: *Sarkhij Monastery*

Grade of Damage: 3

Nature of Damage

1. Supporting columns out of plumb in 16 pillared, domed pavilion. Structure unstable.

2. Detachment of piers from walls in tomb.
3. Damage to stone tracery panels in openings.

Reason for Damage

1. Displacement and rotation of column relative to the pedestal and bracket caused by excessive torsional force of entire structure.
2. Excessive out of plane bending forces resulting in detachment of the two structural components.
3. Out-of-plane bending of the tracery panel.

Suggested Repair Measures

1. Alignment of columns after jacking up of roof. Ensure positive connection using FRP or steel tendons at the bracket level to ensure homogenous action.
2. Grouting of space between the wall and the pier with cement mortar after steel rod anchoring between the pier and wall along the length of the pier ensuring positive connection.
3. After repointing of joints, strips of FRP laminates at the joints on either sides.

8. Name of the Monument: Jaxar Masjid

Grade of Damage: 2

Nature of Damage

1. Felling of sunshade slabs.
2. Widening of joints in the dome masonry.
3. Detachment of piers from walls.

Reason for Damage

1. Excessive vibration of cantilevers leading to slippage from bearing due to insufficient fixity.
2. Excessive lateral displacement of supporting structure of the dome.
3. Excessive out of plane bending forces resulting in detachment of the two structural components.

Suggested Repair Measures

1. Replacement of the cantilevered slab and introduction of stainless steel rods, 7.5 cm into the supporting base and one-thirds into the stone block above. Rods can be embedded in cement mortar.
2. Grouting of widened joints and reinforcement of intrados of the dome with circular FRP tendons to improve tensile resistance.
3. Grouting of space between the wall and the pier with cement mortar after steel rod stitching between the pier and wall along the length of the pier ensuring positive connection.

9 Name of the Monument: *Tax Darwaza, Ahmedabad*

Grade of Damage: 1

Nature of Damage:

1. Widened joints in stone masonry.
2. Collapse of cantilevered segments of ornate window.
3. Falling of decorative stone element from the parapet wall.

Reason for Damage:

1. Due to excessive vibrations leading to detachment of sandstone facing and brick hearing.
2. Slippage of the cantilevered stone elements is a result of their excessive vibration and simultaneous lack of fixity or positive connection.
3. Excessive vibration of vertical cantilever and absence of positive vertical connection led to the toppling.

Suggested Repair Measures

1. Grouting of small gaps in masonry joints with combination mortar (Cement: Lime: Pozzolan – 60%: 30%: 10%).
2. Ensuring positive connection between facing stones and brick core in case of delamination as a strengthening measure.

3. Reconstruction of cantilevered segments with introduction of stainless steel rods, 7.5 cm into the supporting base and one-third into the stone block above. Rods can be embedded in cement mortar.
4. Replacement of the stone element and intervention same as in 2.

10. Name of the Monument: *Syd Usmar's Tomb, Ahmedabad*

Grade of Damage: 4

Nature of Damage:

1. Collapse of three columns, corresponding beams and arches.
2. Widening of joints in dome masonry.
3. Flaking at column bases at column-pedestal junction.

Reason for Damage:

1. Excessive lateral force on the columns bearing the central dome, large shear force acting on beams.
2. Excessive lateral displacements of the supports of the dome.
3. Cyclical rocking of the column on the pedestal resulting in delamination of sandstone surfaces along weak planes.

Suggested Repair Measures:

1. Reconstruction of damaged sections with new material. Tying of the circular ring beam using steel or FRP tendons to act homogeneously.
2. Tensile reinforcement of the dome by introduction of FRP laminates on the intrados.

11. Name of the Monument: *Farid Khan's Tomb, Patan.*

Grade of Damage: 5

Nature of Damage: Total collapse of structure.

Reason for Damage:

Insufficient diaphragm action and excessive lateral displacement must have led to the collapse of the structure.

Suggested Repair Measures

Archaeological reconstruction with anti-seismic measures.

12. Name of the Monument: *Dutch Tank, Ahmedabad*

Grade of Damage: 4

Nature of Damage

1. Dangerous cracks in the dome.
2. Flaking of column bases.
3. Vertical cracking of plinth.

Reason for Damage

Excessive lateral displacement of the supporting columns of the dome accentuated by local soil settlement. Cyclical rocking of the column on the pedestal resulting in delamination of sandstone surfaces along weak planes. Local soil settlement and subsequent foundation disturbance must have caused the cracks.

Suggested Repair Measures

Reconstruction of the structure is recommended due to the extensive damages. Improvement of diaphragm action at roof level using steel ties.

13. Name of the Monument: *Rajar Gate, Ahmedabad*

Grade of Damage: 3

Nature of Damage

Delamination and collapse of facade stones from the core masonry.

Reason for Damage

Loss of bond between the facing stones and the inner brick core due to excessive flexural vibration.

Suggested Repair Measures

Seamless steel dowel pins for positive connection between the facing stone units and core masonry. Bed pointing with cement mortar and steel rods.

14. Name of the Monument: Bhamburda Fort, Ahmedabad



Grade of Damage: 5

Nature of Damage

1. Collapse of large segments of southern concentric cylindrical towers.
2. Vertical cracks at the centre of stone lintels.

Reasons for Damage

1. Heavy inertial mass has attracted large forces; excessive tensile stresses induced in masonry due to to and fro vibrations.
2. Excessive tensile stresses at the bottom fibres of the lintel beam.

Suggested Repair Measures

1. Reconstruction with RCC bond beams. Bed jointing with steel rods every 70 cm. Circular prestressing of cylinder with steel or FRP tendons at 3 m intervals.

2. After supporting and reducing deflection, grouting of the crack has to be followed by pasting of FRP laminates at the soffit and lower one third portion of the lintel on the sides to improve tensile resistance.

13. Name of the Monument: *Khar Sarwar Gate, Patan*

Grade of Damage: 3

Nature of Damage

1. Collapse of wall panel and decorative cornice above the arches.
2. Collapse of roof slabs at the entrance gateway.

Reason for Damage

1. Excessive vibration of vertical cantilevered portion of wall
2. Vertical acceleration responsible for displacing the roof slab and bringing them down

Suggested Repair Measures

1. Reconstruction of collapsed segments with new masonry and with the introduction of positive connections using steel dowel pins between masonry units.
2. Replacement of stone slabs for the roof and introduction of steel connectors with the support for stiffening the diaphragm action.
3. Strengthening of the arches by introduction of ties or prestressed cables.

14. Name of the Monument: *Kanthkot Gate, Kanthkot*

Grade of Damage: 4

Nature of Damage: Partial collapse of wall adjoining the gate.

Reason for Damage

Very heavy inertial mass attracting large seismic forces. Deterioration of binding mortar has aided the failure

Suggested Repair Measures

Reconstruction of collapsed segment with anti-seismic measures.



17. Name of the Monument: *Zaver House, Gandhi Nagar*

Grade of Damage

Nature of Damage: Constructed after the earthquake. This relocated *pal* house is an initiative to conserve the woodcraft of ancient residential quarters of Ahmedabad as a new masonry structure.

Reason for Damage

1. This form of multi-storeyed brick masonry structure with wooden floors and roof is an excellent case for seismic strengthening.
2. Masonry structures of this type are highly vulnerable to lateral forces due to inadequate connection between floors or roofs and walls.

Suggested Repair Measures

1. Connecting the wooden floors to the masonry at all floors.
2. Seating the roof truss over an RCC bond beam with positive connection using bolts.

3. Repointing the bed joints with FRP or steel reinforcement to improve the flexural behaviour of the wall.
4. Strengthening of wall panels between floors and between openings with steel cross braces.

18. Name of the Monument: *Pag Mahal, Bhuj*

Grade of Damage: 4

Nature of Damage:

1. Partial collapse of the uppermost floor of the structure and towers.
2. Severe widening of joints in the Ashlar masonry in upper stories.

Reason for Damage:

1. Excessive vibration has led to the collapse of segments of the upper storey.
2. Lack of sufficient diaphragm action from the floors at all the levels has resulted in severe vibration and deformation of the multi-storeyed structure.

Suggested Repair Measures:

1. Reconstruction of collapsed segments with new or reusable masonry followed by tying up of the floors with the masonry at the edges, for lateral resistance.
2. Bed-joint repointing of the Ashlar masonry with steel rods and cement mortar to improve flexural resistance.

19. Name of the Monument: *Vadi Mah, Nakhatrana*

Grade of Damage: 4

Nature of Damage:

This post and beam structure is ruins of a palace. Excessive displacement of beams and collapse of some beams and columns is observed.



Reason for Damage

The structure is incomplete and hence there is no possibility of any homogenous action. The beams are simply supported and have no fixing. The structure is very unstable against lateral loads-

Suggested Repair Measures

If the structure is to be preserved as a ruin, all beam-column junctions have to be strengthened by means of positive connections like steel rods. This way homogenous action may be ensured in case of lateral loads.

20. Name of the Monument: *Alford High School*, Bhuj

Grade of Damage: 5

Nature of Damage:

1. Ashlar Masonry structure that has suffered extensive damage in the uppermost storey.
2. Collapse of many segments

Reason for Damage: This form of multi-storeyed masonry structure with wooden floors and roof is highly vulnerable to lateral forces due to inadequate connection between floors or roofs and walls.

Widening of joints between masonry units is as a result of excessive flexural stresses induced by vibrations.

Suggested Repair Measures

1. Connecting the wooded floors to the masonry at all floors.
2. Seating the roof truss over an RCC bond beam with positive connection using bolts.
3. Repointing the bed joints with FRP or steel reinforcement to improve the flexural behaviour of the wall.
4. Strengthening of wall panels between floors and between openings with steel cross braces.

21. Name of the Monument: *Katch Monoon*, Bhuj

Grade of Damage: 5

Nature of Damage:

1. Near total collapse of the first storey of this stone masonry structure.
2. Push out of wall segments is seen.

Reason for Damage

Excessive out of plane bending in unreinforced masonry structure with poor connection between floors or roofs and walls.

Suggested Repair Measures

1. Connecting the wooded floors to the masonry at all floors.
2. Seating the roof truss over an RCC bond beam with positive connection using bolts.
3. Reputing the bed joints with FRP or steel reinforcement to improve the flexural behaviour of the wall.
4. Strengthening of wall panels between floors and between openings with steel cross braces.

22. Name of the Monument: *Rao Lakha Chattr, Bhuj*



Grade of Damage: 5

Nature of Damage

Total collapse of superstructure, except the plinth.

Reason for Damage

Very high inertial forces attracted by the mass of the numerous subsidiary solid domes crushed the supporting frame of beams and columns.

Suggested Repair Measures

1. Archaeological reconstruction with anti-seismic measures.
2. Reduction of inertial mass of the structure by replacing the solid domes with hollows

23. Name of the Monument: *Rajolai Chatri, Bhuj*

Grade of Damage: 3

Nature of Damage

Widening of masonry joints in the corbelled dome. Damage and separation of corners of the supporting walls.

Reason for Damage

1. Excessive cyclical lateral displacement of the supporting frame
2. Excessive thrust by the corner columns on to the corner of supporting walls leading to separation

Suggested Repair Measures

1. Reconstruction of the dislocated segments using cement mortar for bonding
2. Grouting of widened joints in the dome and strengthening of the dome by FRP laminates on the intrados.
3. Steel or stone stitching of the corners of the walls.
4. Wrapping of the exterior facade of the wall to improve flexural resistance

24. Name of the Monument: *Sar Togh, Kera*

Grade of Damage: 5

Nature of Damage

1. Monolithic stone element at the top of the spire fallen. Partial collapse of the spire.
2. Extensive damage to the walls of the *mandaps*



Reason for Damage

1. Excessive vibration of the spire leading to dislocation of the heavy element
2. Vulnerability of the spire was high because of deterioration in the bond between masonry units and also due to the high inertial mass.
3. Damage to the walls triggered by the falling stone blocks from the spire.

Suggested Repair Measures

Archaeological reconstruction with anti-seismic measures.

28. Name of the Monument: *Jhir Toshk, Nakhatrana*

Grade of Damage: 3



Nature of Damage

Partial collapse of segments of the mandapa, walls.

Reason for Damage

Inherent instability to lateral forces.

Suggested Repair Measures : Archaeological reconstruction with anti-seismic measures.

26 Name of the Monument: Jain Temple, Kanthkot.



Grade of Damage: 5

Nature of Damage: Total collapse of the temple structure.

Reason for Damage

Factors for the total failure are:

1. Inherent instability to lateral forces.
2. Deterioration in strength of lime mortar and sandstone used in the masonry as binding material.

Suggested Repair Measures

Archaeological reconstruction with anti-seismic measures

27. Name of the Monument: *Jays Mandir, Kanchikot*

Grade of Damage: 5

Nature of Damage: Total collapse of the temple structure.

Reason for Damage

Factors for the total failure are:

1. Inherent instability to lateral forces.
2. Deterioration in strength of lime mortar and sandstone used in the masonry as binding material.

Suggested Repair Measures

Archaeological reconstruction with anti-seismic measures.

28. Name of the Monument: *Ravi ki Vati, Patan*

Grade of Damage: —

Nature of Damage: No noticeable damage to the subterranean structure.

Reason for Damage: The subterranean structure has remained intact due to the confining effect of soil as generally seen in foundations of quake-affected zones.

In comparison to the width of the step well (20-25 feet) the wavelength of the seismic waves is longer and hence there is no drastic effect and the entire structure must have moved in phase.

Suggested Repair Measures: —

Anti-Seismic Retrofit and Rehabilitation

Strengthening of historical buildings is a compromise between requirements of structural engineering and conservation of historic monuments. Intervention must be "as much as necessary, as little as possible" and reversible to give room for better solutions in the future.

Repair refers to post earthquake repair of damages caused by seismic ground motion that does not increase the seismic resistance of the structure beyond its pre-earthquake state. Seismic strengthening comprises technical interventions in the structural system of a building to improve its seismic resistance by increasing its strength and ductility. Strengthening a building before a seismic event is called 'rehabilitation' and strengthening after the earthquake is called 'retrofit' (Tomasevic, 1998). In seismic areas, the basic criterion for repair and strengthening is based on the correlation of the expected seismic loads with the resistance of the structural system, i.e. on seismic resistance verification. Seismic resistance analysis will define the causes of potential damage and indicate the parts of the structure that needs to be strengthened. In case of seismic strengthening, good performance of the whole structural system has to be ensured, therefore both lateral resistance of the structure and its ductility and energy dissipation capacity characteristics need to be verified. About 25 anti-seismic techniques developed in European countries like Italy and Germany are applicable to the Gujarat case.

These anti-seismic retrofit and rehabilitation techniques have been classified as:

Methods to Strengthen Masonry Components

Different methodologies are available for strengthening of different types of masonry walls. The type and quality of the masonry material and a building's structural integrity is the main criteria to be considered when choosing the method of strengthening.

Repair of Cracks

Cracks can be repaired by anyone of the following methods depending on the crack width.

Crack width	Recommended procedure
< 1.0 mm	Injection with epoxy
0.3 to 3 mm	Cracks should be injected with cement grout that contains admixtures against shrinkage
> 10 mm	Damaged area should be reconstructed with bricks

Repointing

The resistance of a wall to lateral and vertical loads can be considerably improved by replacing parts of the existing mortar in bed-joints with mortar of better quality. This is applicable where bed-joints are level and mortar is of poor quality and the masonry units are good.

Reinforced-Concrete Jacketing

In case of seriously damaged brick masonry walls, or where there is a need to strengthen the entire structure, the application of a reinforced concrete concrete jacket on both sides of the wall is a way of improving its lateral resistance and energy dissipation capacity.

Grouting

Systematically filling the voids by injecting a cementitious grout is an efficient method of strengthening. After hardening the injected grout will bond the loose parts together into a solid homogeneous structure. A cementitious mix (90% Portland cement and 10% pozzolans) is injected into the wall through injection tubes and nozzles built into the joints between the stones uniformly over the entire wall surface at 0.5 to 1.0 m intervals and grouting proceeds from the bottom. Both tensile strength and rigidity of the stone-masonry is greatly enhanced after grouting.

Prestressing

The shear resistance of the wall is determined by the maximum principal tensile stresses, which develop in the wall at ultimate state. As the principle tensile stress is a function of the stress state in the wall, the critical situation at ultimate state is improved by prestressing the wall vertically and/or horizontally. Holes are drilled through the central part of the wall at uniform distances so that after prestressing uniform additional compression is induced in the wall's vertical or horizontal section thereby increasing its lateral resistance. Steel tendons or bars are placed in the holes and anchored on steel plates after prestressing. Tendons and prestressing bars can be removed from the walls in case a better solution for strengthening is developed.

Strengthening Using Fibre Reinforced Plastics

Fibre Reinforced Plastics or F.R.P. are used extensively where strength has to be combined with lightweight and durability. High mechanical strength, resistance to chemical agents and impermeability to water are their other advantages. F.R.P. is used, as an adhesive material is non-invasive and completely reversible, a favourable feature for historic buildings.

Strengthening Using Shape Memory Alloys

Shape Memory Alloys are metals endowed with very unusual thermo-mechanical properties associated with reversible crystallographic transformation from Austenitic to Martensitic phase. In effect two different types of S. M. A. devices application are possible for seismic strengthening. (1) In series with conventional steel tendons for masonry post-tensioning, to increase in-plane shear and flexural capacity of masonry structural elements. (2) In series with horizontal conventional steel ties, to improve out-of-plane behaviour.

a) Methods to Improve Structural Integrity of the Structure as a Whole.

To fully utilise the potential resistance and energy dissipation capacity, the monolithic behaviour of masonry structures should be ensured. The possible vibration modes of a masonry building during an earthquake depends on how the building is interconnected and anchored at floor and roof levels. Therefore, besides strengthening of individual structural components, the structural system as a whole needs to be strengthened to ensure structural integrity. The various methods suggested for improving structural integrity are:

Tying of Walls with Steel Ties

Steel ties are to be introduced immediately under the floor structure. Reinforcing bars with threaded ends to be bolted at the ends of the walls on anchor plates, are used.

Interventions in Floor and Roof Structures

One of the main reasons for poor seismic behaviour of existing masonry structures is a lack of proper horizontal diaphragm action of floor structures and roofs and connection of the horizontal diaphragm to the structural walls. If adequately anchored to the walls, rigid floor diaphragms and tie beams prevent the out-of-plane vibration and possible collapse of walls.

Repair of Corners and Wall Intersections

Wall corners and intersections are frequently damaged during earthquakes even if they are tied with steel ties at floor levels. The wall intersections or corners are strengthened by means of stone stitching stones or metal stitching.

Strengthening of Walls by Confinement

By confining plain masonry walls with vertical confining elements like tie columns placed at wall corners, intersections and vertical borders of large openings the lateral resistance and energy dissipation capacity of a masonry building is greatly improved.

Brick masonry structures with horizontal r. c. tie beams and rigid floors are suited for this kind of an intervention.

Strengthening of Structural Elements

Dry stone masonry offers very high strength in compression, but their joints provide limited shear and tensile resistance as they depend only on friction. A positive connection between the stone blocks may be required in some cases and this can be achieved using dowels, cramps, bars, special tie bars or structural connections inserted through specially prepared holes in the joints without being visible from outside.

Strengthening of Secondary Elements

Repair to secondary elements like cornices, parapets, medallions, sunshades, facing stone slabs, etc., primarily involves the reestablishment of effective connections, using methods such as insertion of pivots, nails, dowels, clamps, stirrups, anchorages, etc. Grouting of the holes drilled to accommodate connectors will improve effectiveness of the system.

Methods to Isolate Seismic Waves from the Structure Reduction of the Transferred Energy

This is a complicated and costly, but radical solution that isolates the structure either at the foundation level or at the floor level from seismic movements being transferred to it.

The remedial action consists of cutting the structure to create a joint to allow certain relative movement. These movements are partly restrained by special devices that act in the one or both of the following ways:

Dissipation of Energy

Changing the Natural Period

Base Isolation Technique

Seismic Isolation, including Base Isolation (B.I.) and passive Energy Dissipation (E.D.), is a relatively new technique, which

has already been applied to the seismic protection of historic buildings.

Base Isolation reduces the seismic loading on the structure by interposing a horizontal flexible layer between the foundation and the superstructure.

Reduction of Induced Forces

A reduction of induced forces can be achieved by the following ways:

1. By reducing the masses especially at upper levels
2. Reducing the planimetric asymmetries that may produce torsional effects in the structure and increased stresses in walls and connections.

Mathematical Modelling

The purpose of analysis of historic structures under static and dynamic loading to understand their behaviour is essential for safety assessment and design of retrofiting measures. Unlike modern engineered structures, analysis of historic structures presents complexities due to various reasons. Historic structures primarily are constructed out of brick or stone masonry with lime mortar bed jointing. Unreinforced masonry displays a complex non-linear mechanical behaviour characterised by low tensile strength and high stiffness.

Generalisation of historic structures becomes difficult due to the following reasons:

1. Variability of material properties due to the use of locally available construction materials,
2. Varying degree of workmanship
3. Additions and alterations, both structural and cosmetic over a period of time

In the present work SAP2000 NL software has been used to model the structural behaviour of a small symmetrical *Chatri* in Bhuj, partially damaged in the earthquake and the results are compared to the actual damage. The *Chatri* is a small, domed

sandstone structure, symmetrical in plan. The dome, constructed by the corbelling technique rests upon 12 sandstone columns. The entire structure stands on a raised plinth of sandstone.

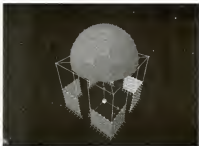
The salient features of this model are:

1. The engineering properties of material – sandstone are as follows: Young's Modulus of Elasticity = 7×10^6 KN/m² and Poisson's ratio = 0.17 (from experimental values). The supporting walls of the structure have been modelled with shell elements.
2. The columns and beams have been modelled with frame elements.
3. The hemispherical, hollow dome has been modelled with shell elements.
4. The sunshades and flat roof slabs are modelled as uniformly distributed load in the negative Z direction acting on to the corresponding beams.
5. All the six degrees of freedom are restrained (fixed boundary condition) for the lowermost nodes of the structure.
6. All other nodes in the model have all six degrees of freedom activated.
7. Frame releases for moment (i.e. no moment transfer) in the Z direction have been provided for the beams and columns.

Shown below, in figure is the Graphical User Interface or GUI of SAP2000 showing the three-dimensional structural model of the symmetrical structure. The use of shell elements for the supporting walls and the dome and frame elements for the beams and columns can be seen.

The following figure shows an output of the dynamic analysis under the natural frequencies of the structure. The deformation of the structure is seen along with the undeformed wire shadow of the structure. The period of vibration for the structure in the first mode is 0.6855 seconds.

First Mode Shape for Vibration Analysis on SAP2000 GUI



The following figure shows the stress outputs for the structure under earthquake ground acceleration by the response spectrum method. Response Spectrum Case 1 is characterised by the following parameters in this model:

1. Damping Coefficient of 0
2. Response Spectrum Function UBC94S3 (Response Spectrum for Soil type 3 – Loose and Cohesionless soil, Uniform Building Code)
3. A combination of acceleration along X-direction (100%) and global Y-direction (30%).

Stress output for shell elements of the structure under earthquake ground acceleration on SAP2000 GUI

The following were the prominent damages observed in the structure as a result of the seismic forces:

1. Widening of joints in the masonry of the corbelled dome
2. Dislocation of masonry blocks from the corner of the support walls



The widening of the joints in the corbelled masonry dome is due to the excessive deflection induced in the supports of the dome. SAP2000 GUI shows evidence of tensile stresses in the lower areas of the dome.

Excessive forces taken by the corner column are responsible for dislocation of the masonry units. SAP2000 GUI shows the distribution of stresses in the support walls. High compressive stresses are observed in the region being discussed.

Conclusions

Structures cannot be made earthquake proof, only resistant to earthquakes. There is a need to adopt the internationally accepted anti-seismic retrofit and rehabilitation techniques to the conditions in India and simultaneously train manpower in their use, to ensure conservation of our monuments for posterity.

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Conservation and Restoration of a Shah Jahan Period Colonnade

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The Indian collections at the Victoria & Albert Museum (V&A) bring together a substantial part of the original Indian Museum, founded by the East India Company at the beginning of the nineteenth century and transferred to the India Office in 1858 and collections built up by the South Kensington Museum from its own inception following the Great Exhibition at the Crystal Palace in 1851. These now form one of the most comprehensive collections of their kind in the world and with the collections at the British Museum and the British Library, make London the most important centre for the study of Indian art outside India itself. The V&A's collection comprises architectural materials, sculptures, paintings and a wide range of the decorative and performing arts.

Sadly, since 1955, when the Indian galleries leased by the Museum since 1879 were demolished to make way for Imperial College, only a relatively small part of the collection has been on permanent display. But in 1988, the Museum started a programme to re-display its Indian collections and in 1990 opened the Nehru Gallery of Indian Art. Over the past twelve years, the Museum has actively made its collections accessible to public and scholars alike, both national and international, displaying and publishing them and welcoming visitors to the reference collections. Now, it plans to increase this accessibility still further, both through a programme of digitisation and web access and by turning its

attention again to achieve a larger area of public display within the Museum as part of an overall South Kensington master-plan. The collection includes a number of large architectural pieces, which represent particular conservation and display challenges. One such is a serpentine colonnade from a royal pavilion at Aymer, dating to the reign of the Mughal Emperor, Jahangir. This was displayed as part of the Indian Heritage exhibition of 1982 and is now installed in the Nehru Gallery. A second is a gateway made in Gwalior for the Calcutta exhibition of 1883, partly built into the wall structure of the V&A's Raphael Gallery and partly in store. A third is a set of columns and architraves, which were parts of a colonnade from Agra.

The History of the Colonnade

This colonnade was originally part of a marble pillared hall, which fronted a bath complex in the Agra fort, constructed in the early years of the reign of the Mughal Emperor, Shah Jahan, as part of his extensive rebuilding of Akbar's original fort. Shah Jahan, the great architectural patron of the Mughal dynasty, drew on the most advanced trends adopted by his father, Jahangir and grandfather, Akbar and developed a new aesthetic and a style, which was a major influence on the architecture of the subsequent two centuries. Amongst other features, the use of white marble and a very fine, highly polished white stucco from Gujarat (*chuna*) became the favourite veneer of imperial buildings.

By the early 19th Century, the baths at Agra fort were reported as being in "ruinous condition" and the Marquis of Hastings, Governor General of India from 1813 to 1837, started to make arrangements for the marble cladding of the bath complex to be stripped and sent to Calcutta, with the intention of presenting at least part of it to the Prince Regent (the future King George IV). In the event, the marble was never despatched, but was sold at auction by his successor, Lord William Bentinck and dispersed without trace.

The portico itself, which consisted originally of a columned hall with trabeated arches on its three outer sides, was not part of this sale and most of its constituent parts have now been located. Two fragments still lie in the fort; a shaft and capital and two columns are now in the Taj Museum; and two shafts of capitals and two shafts of half columns are to be found built into the porch of the Agra Cerut House. The largest known section, consisting of five columns (4.2 metres high), which form four intercolumniations (of



Part of the Colonnade made on Display in the Victoria Museum

2.6 metres) with architraves supported by consoles (c. 5 metres in total height), was acquired in 1886 by the South Kensington Museum (now the Victoria & Albert Museum) from Sir Alfred Lyall, Lieutenant Governor of the North West Provinces (1881-7) and Member of India Council in London (1887-1902). It had been sent by Lyall, in his capacity as a committee member to the Royal Colonial and Indian Exhibition held in London that year, on the condition that it should be presented to the South Kensington Museum at the close of the exhibition. After the exhibition, it was installed in the galleries on Exhibition Road, which were then the home of the 'Indian Museum' and remained there until 1955. Then like much else in the collection, it went into storage, awaiting the time when space could be found and it could be cleaned, conserved and redisplayed.

Stylistically, the colonnade demonstrates the continuity and the eclecticism of late Mughal art and architecture. It continues the

constructional mode of the earlier Mughal period, which imitates forms and techniques of wooden construction, which themselves derive from both Hindu and Muslim forms. But its particular use of marble is typical of the work of Shah Jahan's reign at the height of the Mughal period. Its extensive floral decoration in polychrome stone inlays (the Italian technique of *petra dura*) is both a reflection of the refinement in craft techniques by this period and a demonstration of the influence of forms and methods, which originated in Renaissance Europe. The inlays include carnelian, beryl and both black and variegated marbles from different sources in Rajasthan.

Conservation and Restoration

At present, the overall condition of the colonnade is surprisingly good, although the marble has become rather dirty over time and the inlay has suffered from a visually unpleasant restoration in which much of the inlay has been replaced with coloured plaster, which is no substitute for the original scheme. If the marble were fully cleaned, the old plasters removed and the semi-precious stone inlay carefully restored, the colonnade could almost be returned to its original magnificence.

Although the Museum's normal attitude to the conservation of fine stonework would be one of careful preservation (accepting previous losses and damage) rather than restoration, there is some justification in this case for adopting a restoration approach. The colonnade depends almost entirely for its visual effect on the rich contrast between the semi-transparent white marble for the architecture and the gleam of semi-precious stones (such as carnelian and beryl) of its decorative inlay. If this contrast is not fully exploited, then much of the character of the colonnade will be lost when it is finally displayed.

In the mid 1980s therefore, as part of a scheme to redisplay the Indian collections in the Museum, the V&A asked a company (Herbert Read Ltd of Exeter), which had considerable experience

in the restoration of fine stonework, to quote for the full restoration of the inlay and the installation of the colonnade in the proposed gallery, using stainless steel fixings throughout. The plan was for the work to be supervised by the Museum's conservation department and much of the cleaning would be also carried out by our own stone conservators.

Full conservation, restoration and installation in the gallery was estimated to cost at that time in the region of £200,000. To start the project, the Museum allocated £13,000 for the financial year 1985-6 and embarked on the work on one of the five columns. The marble on this column was fully cleaned, the old plasters removed and the semi-precious stone inlay carefully restored. Unfortunately, in the intervening time, the proposals for the new gallery and its design were fundamentally changed, the smaller Agra colonnade was incorporated into the design of the new Nehru Gallery of Indian Art and the fund-raising for the Agra colonnade was put on hold. Now, after a gap of several years, the Museum is once again reviewing the project to restore the colonnade.

One of the most compelling reasons for advancing a full-scale conservation programme for this important architectural composition is the serious threat that now exists to other *jama'ara* buildings that remain *in-situ* or in unprotected locations in Agra. As India has become more industrialised, emissions of damaging pollutant gases such as sulphur dioxide are rising and these are causing noticeable degradation in the fragile white marble and semi-precious stone inlay of these unique buildings – matter that is of concern to all the relevant authorities in India, who are working to address the problems, both by controlling emissions and by seeking methods of dealing with the local issue of marble decay.

Over the past twenty-five years there has been a noticeable change of colour in many buildings in Agra. The clearest symptom of pollution attack is the discoloration of white marble,

so that in the 1980s, in those areas that were not washed by rain, it was gradually turning into a rather dirty brownish yellow. This change in colour presaged the rather more serious damage that could be expected from acid deposition. Already by the mid 1980s, there were signs that the surface of the Taj Mahal was being etched by the weak acid solutions created by the mixture of pollutant gases and rainwater, as the acids ate deep into the matrix of the marble, dissolving the calcium carbonate, which bonds the marble together.

Indian white marble is particularly vulnerable to attack. Like many Greek marbles, it has a very large crystalline structure, which degrades rather faster than the fine grained marbles of Carrara with their tendency to powder away slowly. The very crystalline marbles tend to lose large clusters of crystals in dramatic bursts when attacked by acids.

During the past twenty years, there has been a great deal of research on the nature of stone decay and the means by which it could be prevented or halted. Although certain treatments had been developed by the mid 1980s (the V&A had been deeply involved in this work), no honest conservator or scientist pretended that there was a method by which deteriorating stone outdoors could be stabilised for more than twenty years at the most. This remains true even though there are now exciting possibilities opening up with the use of lasers for cleaning and of experiments to grow marble crystals and rebuild the surfaces of objects. For the foreseeable future, therefore, when we have the opportunity to keep stonework indoors, in an environment, which will not only help to preserve it but also make it easily accessible for future study, we feel that we have a unique opportunity. Historical circumstance has placed an important architectural composition in our custody, in an environment for the present safer than its original one. We have a strong obligation to maintain and display it to the best possible advantage and are now seeking the means to do this.

Stone Conservation and Future Research – An Indian Perspective

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Stone has been one of the basic building materials used in India since very early times. Being seemingly durable in nature, a wide variety of stones, depending on their availability workability, were used to build houses, memorials, palaces, forts, places of worship and also for carving out sculptures. Since geological topography varies considerably in the country, a variety of stone types were used for these purposes. The examples of craftsmanship in stone are evident throughout the length and breadth of the country. This vast cultural heritage, though of durable nature, has started showing signs of decay manifested in many forms over the period, thus necessitating search for suitable methods and materials for checking this onslaught. Some work has already been done in this field in India but there is clearly a need for far more greater and concerted effort involving various disciplines of science.

Common Indian Stones Used in Northern Region

Sandstone, marble and quartzite are the most common types of stone used here. A variety of sandstones are available in the region and have been used for buildings and sculptures, especially in the regions of Agra, Mathura and Delhi. The Jaisalmer fort was constructed out of yellow sandstone. Marble was used as a veneer for Taj Mahal. Quarzitic stone rich in mica had been used extensively in the temples of Garhwal and Almora.

Table 1: Types of Stones Used in Indian Monuments**Monument / Historical Building Stone****Sandstone**

Red fort, Agra; Khajuraho temples; Jama Masjid, Delhi; Qutb Minar, Delhi; Rameshwaram temple; Pathapur Sūtra; Sun temple, Modhera; Rani-ki-vav, Patan; Sanchi stupa; Sikandara, Agra; Mathura sculptures; Lingraj temple; Puri; Udaigiri Caves, Khandagiri caves, Orissa; Bagh Caves; Portuguese fort, Diu; Asokan pillars; Rajasthan monuments; Belu ka Makbara, Aurangabad, Victory Tower, Chittorgarh; Sibsagar temple, Assam.

Marble

Taj Mahal, Agra; Moti Masjid, Agra; Etmed-ud-Daulah, Agra; Jaiwant Thada, Jodhpur; Dilwara temples, Mt. Abu; Victoria Memorial, Kolkata.

Granite

Gomateshwara, Sravanbelgola, Thousand pillared temple, Hanamkonda; Vivekanand rock memorial, Kanyakumari (Charnockite); Shore temple, Mahabalipuram (Charnockite); Brihadeswara temple, Thanjavur; Vidhan Sabha, Bangalore; Golkonda fort, Hyderabad; Chausath Yogini temple, Khajuraho; Baul: Kalash temple, Ellora, Ajanta caves; Elephanta, Mumbai; Bhaja caves; Carh caves.

Khondalite

Sun Temple, Konark; Puri temples.

Laterite

Churches and convents, Goa; Kerala monuments.

Quartzite

Almora temples; Qutb Minar, Delhi; Chamra monuments, Himachal.

Lime stone

Dwarka temple, Monuments at Avantipur, Kashmir.

Limy-shale

Puthpagiri temples, Cuddapah.

Soapstone

Hoyasleswara temple, Halebid; Chenna Kesava temple, Belur.

Sculptures of Mathura region were carved out of buff, red and spotted sandstone.

Stones Used in Eastern Region

Sandstone and khondalite were the chosen stone types used here. A large number of monuments in this region were built of sandstone available in plenty locally. Sun temple at Konark and a number of temples at Puri were built out of khondalite stone. Both sandstone and khondalite were also used for making sculptures.



Beautifully Carved Wall of Khondalite Stone in a Temple in Eastern Part of India

Stones Used in Western region

Sandstone, marble, basalt and limestone were used at different places in this region. For example, the cave temples at Ellora and sculptures at Elephanta were carved out of basalt rocks.

Limestone was used in the *Dwarka* temples. *Dalwara* temples at Mount Abu and *Jainant Thada* at Jodhpur exhibit extensive use of marble. Lignite stone has also been used in some churches of Goa.



Granite Rock-cut Cave at Mamallapuram, Tamil Nadu

Stones Used in Southern Region

Granite is the most commonly used stone in southern part. A variety of granites like white, red and black have been used for the purpose. The examples are Shore Temple at Mahabalipuram (charnockite), gigantic sculpture of Gomateshwara at Sravabelgola, Virrekaramda Rock Memorial at Kanyakumari. In some places like Halebid and Belur, steatite or soapstone has been used for constructing temples.

Stones Used in Central Region

Sandstone has been used quite frequently in this region. Examples are groups of temples at Khajuraho, Buddhist stupa at Sanchi, etc. A list of some of the important monuments and the stones used for these has been presented in Table 1.

Types of Deterioration and Their Causes

Observations made by several scholars clearly indicate that the Indian heritage in stone is susceptible to all three types of decay, viz. physical, chemical and biological. Depending upon the climatic condition of the region where these stones are present, any one of these factors of decay could play an important role in their deterioration. However,



Splitting of Layer is a Major Problem in Sandstone



Soiling Surface Can Spoil the Beautiful Surface of Monuments

the extent of decay also depends upon whether the stone is present inside or outside. Usually, the rate of decay is more outside because human intervention in controlling the action of different deteriorating agencies is more effective inside. A variety of problems like - soiling of surface, formation of cracks and splitting of layers, crumbling of surface into powder, crust formation,

staining and erosion of surface, growth of biological agencies like algal, moss, lichens, higher plants etc., have been observed by several workers.

The reasons are also quite varied. The presence of soluble salts causes efflorescence resulting in crumbling of surface. The presence of air pollutants such as sulphur dioxide and SPM results in the formation of surface crusts. The inherent impurities present in stone like clay minerals or minerals, which get easily attacked or dissolved by moisture, result in the formation of stains, cracks and erosion of surface. The continuous presence of moisture may result in the growth of algae or moss. In relatively unpolluted environment, lichen growth is quite common. Human vandalism resulting in physical damage is also quite common in India. Many a time an improper treatment could also lead to further aggravation of the problem. Use of incompatible materials during construction like iron clamps or dowels can also be responsible for the damage.

Conservation Measures - Past and Present

The history of conservation of stone materials in India, about 100 years old, is the history of preservation of its monuments. Although there are some instances of repair of monuments earlier to this also. For example, that of Taj Mahal in 1808, Fatehpur Sikri and Sikandara in 1815, Qutub Minar in 1826 and Ahmednagar Fort in 1867. However, regular conservation could be ascribed to Sir John Marshall who prepared a Conservation Manual for Archaeological Survey of India. At present, most of our monuments and historic buildings are looked after either by Archaeological Survey of India or by State Archaeology Departments depending upon their historical significance. Many important structures are also under the care of charitable trusts and public institutions.

A large number of important monuments and sites such as Taj Mahal, Fatehpur Sikri, Sun Temple at Konark, monuments at Mahabalipuram, some churches and convents at Goa, temples at Khajuraho, Hampi monuments, Brihadeshwara temple at Thanjavur etc., have been included in the World Heritage List to give due importance to their conservation. On account of a very large number of monuments and limited resources, the conservation interventions have centred mostly around replacement of defective stone, strengthening of foundations, stoppages of leakage of water and occasional removal of dust, dirt and biological growths. The stone sculptures are generally cared for by different museums controlled by Central Government, State Governments or in many cases even by private trusts. Here the treatments have focused mainly on cleaning of surface and joining of broken parts.

In some cases, attempts have been made to remove soluble salts, different types of accretions and consolidation of fragile surface etc.

Researches Done in the Past

Although, India possesses a very vast cultural heritage in stone and the problems posed by these are also of varied nature, the stone conservation research as a discipline has not received the attention that it deserves. At best the efforts made so far could be described as occasional and piecemeal, as most of the earlier efforts were directed mainly towards arresting the decay with available means with little or no attention towards systematic stone conservation research. Another important reason for this dismal state of affairs is the dearth of scientific community interested in this field, which requires multi-disciplinary approach. Nevertheless the field has seen some growth in recent years with many groups trying to contribute by perusing general and specialised articles on various topics related to stone conservation. These articles can be classified into three main categories - articles dealing with various problems of stone deterioration in general or with reference to a particular monument, articles describing the treatments provided to stone monuments or sculptures and



Victoria Memorial Hall, Kolkata Constructed out of Marble

articles based on scientific studies done in the laboratory either to characterise the stone to understand the mechanism of weathering or to test the efficacy of different products which could be used for conservation. Several articles⁵⁻¹⁰ have discussed in general the problems faced by some important Indian monuments. Problems of individual monuments have also been highlighted by several workers. Taj Mahal being one of the most widely known monuments of India, its conservation status has been a subject of several studies¹¹⁻¹⁵. The problems of deterioration of Shore temple, Mahabalipuram because of its proximity to sea, also received the attention of several workers^{16,17}. The problems of monuments situated in colder climates were discussed by Fonia¹⁸ and Gupta *et al.*¹⁹. The deterioration of stone in Indian monuments as a function of building designs and functional environment was discussed by Sharma *et al.*²⁰. Agarwal²¹ drew attention towards the deterioration of marble used in Victoria Memorial, Kolkata. He also reported the corrosion of copper and iron clamps to be responsible for the presence of green and reddish-brown patches over the marble and consequent decay of marble. Kamalakar *et al.*²² studied the problems of Pushpagiri (A.P.) monuments made up of limy-shale stone having iron inclusions.

The problem of deterioration of composite masonry stonework was addressed by Sharma *et al.*²³. Besides studying the deterioration, problems of important monuments, conservation problems of stone sculptures were also studied. Thus, factors responsible for the exfoliation of sandstone, which is one of the most commonly used stones in India, were listed by Rawat²⁴. Agarwal²⁵ and coworkers²⁶ reported the various types of deterioration observed in sandstone sculptures of Mathura. In a comprehensive review of the subject, Jain *et al.*²⁷, discussed the types and problems of sandstone as well as the work done around the globe for its conservation. Similarly, Jeyaraj²⁸ highlighted the problems of Amaravati limestone sculptures housed in Government Museum,

Chennai. From the above-mentioned studies, it can be concluded that various types of physical and chemical deterioration could be observed in Indian stones. On account of tropical climate, the problem of bio-deterioration is also quite common in India and has received the attention of some scholars²⁹⁻³¹.

Thus, the role played by bacteria and fungi³² in the deterioration of stone and that of higher plants in the deterioration of historic buildings³³ was discussed by Mishra *et al.* Control of algal growth, a very common problem on monuments and sculptures present outdoors was discussed by Mishra and Jain³⁴. Jain *et al.*³⁵ and Saxena *et al.*³⁶ discussed in great detail the mechanisms involved in biodeterioration of stone. With growing industrialisation of country, the phenomenon of air pollution has affected all walks of life, giving rise to the thought that the materials of cultural heritage might have also got affected by it.

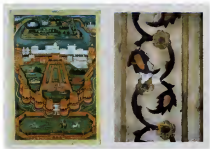
The phenomenon got due attention when doubts were raised about the effect of gaseous emissions like sulphur dioxide released by Mathura refinery on the marble of Taj Mahal. Studies³⁷ were then conducted to study the deterioration of Taj marble because of air pollution and consequently a number of steps were taken to reduce the pollution around Taj Mahal. After a decade, studies³⁸ on Taj Mahal were again carried out to study its deterioration. Fortunately, so far the fears regarding the decay of Taj Mahal due to pollution have not been found true but the problem had acted as a catalyst to raise the issue of deterioration of cultural heritage on account of air pollution³⁹⁻⁴⁷, which is bound to grow with increasing developmental activities. The mechanism of decay of stone because of air pollutants has been explained in detail by several workers such as Jain *et al.*^{42, 48} and Adam^{49, 50}. In order to save the cultural heritage in stone, John Marshall long back prepared a detailed manual outlining the principles and techniques of conservation. Recently, Grover⁵¹ again recounted some of these principles. But in the past, most of the efforts were directed towards attending to the most

immediate problems of weathering as the task at hand was enormous and very limited skilled personnel were available to look after the very large number of heritage in stone. Literature mentions some of these efforts.

The problem of stabilisation of foundation of Qutub Minar was described in detail by Saxena *et al.*⁵² and Batra⁵³. Sharma *et al.*⁵⁴ described the conservation work done at Surya Narayan temple in Lord Jagannath temple complex involving deplastering and replacement of damaged stone. Suggested conservation measures in respect of Shore temple, Mahabalipuram were reported by Subramanian⁵⁵ and Subbiah *et al.*⁵⁶. Sharma *et al.*⁵⁷ found the use of PMC grouts suitable for structural strengthening of Ashlar masonry at Lord Jagannath temple, Puri. Raghavendra Rao and coworkers⁵⁸ described the steps taken at Ajanta to consolidate the weak and friable stone with dilute epoxy resin and filling of gaps with epoxy mixed with rock powder. Bhatia⁵⁹ gave an account of the conservation work done at Harid Mansil, Raza Library, Rampur. Similarly, some other workers have reported the conservation work done by them on different monuments⁶⁰⁻⁶⁴. According to Singh *et al.*⁶⁵ good results were obtained by using clay pack method for the cleaning of Taj Marble. Pandey⁶⁶ and Agrawal *et al.*⁶⁷ recounted the methods and materials used in the conservation of marble statues and canopy at Raj Bhawan, Lucknow. Sharma⁶⁸ narrated his experiences in the removal of discolouration from ancient marble and plasters. Agrawal *et al.*⁶⁹ described the conservation treatment provided to sandstone sculptures of Mathura Museum. Upadhyaya⁶⁹ described the preservation of Asokan pillars at Bihar. Bisht *et al.*⁷⁰ used Bleyer's cement for joining sculptures but noticed the problem of appearance of stain under high humidity conditions.

Conservation problems of kankar stone sculptures were discussed by Hasan *et al.*⁷¹. Tandon⁷² reported successful use of a variety of chemicals like *Sasstint*, zinc silico fluoride, benzalkonium chloride, Thelux-B, *Thiomersal* etc., for the removal of biological

*Conservation and Restoration of a Shah Jahan
Period Colonnade*
-D.A.Swallow



Agni Fort, Maghal, C. 1776-1780. The
Facing Shows the Area of Marble Clad
Buildings Developed by Shah Jahan. The
Back View Located to the Left of the Marble
Terrace Overlooking the River Facing the
Dewan-i-Khas.

Plaster In-situ Denotes the Effect of the
Constant Increase Marble and Semi precious
Stones, Which is seen in Better Effect in
Those Areas Which Still Retain Their Inlay

*Stone Conservation and
Future Research-An Indian Perspective*
-K.K. Jain



Sandstone Sculpture in a Museum



Marble Sculpture in a Temple



A Group of Temples Built of Sandstone at Joprhara in Northern Bagmati



Granite Temple at Hampi



On Site Working of Shiva Temple at Hampi

growths from Khajuraho temples. Jain⁷³ also used zinc silico fluoride for the removal of biological growths on Vishvanath temple at Khajuraho. Besides attending to the various demands of conservation work in the field, laboratory studies were also made from time to time to understand the basic nature of the stone/rock, weathering products, the mechanism of weathering and also to test newer methods and materials for conservation. The stones used in some important Indian monuments were reported by Gangopadhyay⁷⁴ and Mathur⁷⁵. Agrawal *et al.*²⁶ studied the nature of red and buff spots on Mathura sandstone. The brick materials used in Victoria Memorial with regards its conservation were studied by Agarwal⁷⁶. Lal⁷⁷ studied the weathering of some monuments in basalt & ruff, granite and khondalite by determining the leaching index and suggested that chemical weathering takes place due to kaolinisation of feldspars, limonitisation of garnets and desilicification of albites as well as leaching of alkalis followed by accumulation of sesquioxides. Bhargava *et al.*⁷⁸ carried out petrology, x-ray diffraction and chemical analyses of stone samples from monuments at Bhubaneswar and compared the results with quarry samples to conclude that besides physical weathering, chemical deterioration has taken place in these monuments due to leaching of minerals and transformation of feldspar (orthoclase) to kaolinite through illmenite. Petrological studies of samples from Shore temple, Mahabalipuram and Gopeshwara statue, Sravanabelagola were carried out by Singh *et al.*⁷⁹ to explain the deterioration in both the cases. Deterioration of monuments because of corrosion of dowels was studied by Jain *et al.*⁸⁰.

The discolouration of Taj Mahal marble was studied by Agrawal and coworkers⁸¹, who gave various reasons for it. They also observed the presence of calcium oxalate in the crust. Sharma *et al.*⁸² also concluded that the yellowing of Taj Mahal marble was due the deposition of SPM. From their studies, Sharma *et al.*⁸³ concluded that a patina of oxalic acid over marble is protective

in nature and further⁸⁴ studied the metasomatic action of ammonium oxalate on marble to conclude that this could help in stopping further dissolution of eroded surfaces. Veerabagavan *et al.*⁸⁵ and Sharma *et al.*⁸⁶ studied the accumulation of dust on floors of buildings in Red Fort as a result of visitors. The characteristics of accretionary deposits on stone surface as a result of changes in the environment around monuments was also studied by some workers⁸⁷. Kamabakar and coworkers⁸⁸ suggested that the ritual of applying lime wash on granite walls of temples resulted in their deterioration through formation of gypsum leading to pitting of surface ultimately. Cleaning of surface is an important step in the conservation of stone surfaces and from time to time a variety of methods and chemicals have been used for the purpose. Based on their laboratory studies, Singh and coworkers⁸⁹ have warned against the use of commercial washing powders for cleaning of stone surfaces especially in case of historic buildings. For removal of rust stains from marble surface, a problem commonly noticed in Taj Mahal, attempts were made to find out suitable chemical formulations for its removal without damage to stone surface by Saxena *et al.*⁹⁰

Tandon *et al.*⁹¹ also suggested the use of soda water for removal of lime from a sculpture. Hotchand *et al.*⁹² reported a method for cleaning of marble surface, which according to them was yellowed on account of air pollution. For controlling algal growth on stone surfaces, Mishra and Jain⁹⁴ reviewed the various chemicals used by different workers in the past. Mishra *et al.*⁹³ also described methods for collecting algal samples in the field by conservators. Weathered and unweathered stone samples from Khajuraho were analysed by Tandon⁷² who also measured meteorological parameters and studied the biological growths found on the stone surface. According to him, lichen acid and oxalic acid were involved in the biodeterioration of these temples. Jain *et al.*⁹⁴ studied the effect of biogenic acids viz. oxalic, succinic, malic, lactic and α -ketoglutaric on marble, sandstone,

khondalite and coral stones and concluded that calcareous stones are more susceptible to damage by biogenic acids and the damage is also directly proportional to available surface area. Lichens are quite frequently found on stone surfaces specially in unpolluted atmosphere. Some studies were made to determine the pattern of their growth and their relationship with deterioration of monuments. For example, studies to identify the various species of lichens growing on Lucknow monuments were conducted by Singh *et al.*⁹⁵. From their studies, they ruled out the possibility of chemical deterioration in these monuments and suggested physical decay only. The growth of higher plants like papal has been responsible for extensive damage to several monuments. The mechanism of decay, methodology and materials required for their eradication have been discussed in detail by Agrawal and coworkers in their monograph⁹⁶. Keeping in mind the problem of air pollution, some workers made laboratory studies to determine the effect of different acidic gases over marble^{97, 98}.

Over the years, the use of synthetic polymers has increased globally for the conservation of stone. A variety of these polymers are available in the market and have been used for different purposes like consolidation and water repellency. Sharma⁹⁹ discussed the limitations of present day water repellents and the requirements of an ideal treatment for historic buildings. Based on laboratory studies, Singh *et al.*¹⁰⁰ concluded that organo-silanes gave better account of themselves as consolidant for khondalite stone among a group of polymers used in the study. Considering the limitations of organic polymers, Ganorkar¹⁰¹ and coworkers¹⁰² developed some inorganic polymers for use on marble surface against sulphur dioxide attack and found the results to be satisfactory.

In many instances, conservation treatment involves restoration of parts of historic buildings. In the absence of sufficient scientific data on ancient materials and methods^{103, 104}, many a time use has been made of cement mortar in monuments and historic

buildings. Considering the unsuitability of cement mortar for restoration purposes because of its tendency to give out salts, the possibility of using lime based mortars having organic additives as mentioned in ancient Indian literature was explored by some workers¹⁰⁵⁻¹⁰⁸. Though the studies are preliminary in nature, the results are promising and require extensive laboratory and field trials before this type of mortar could be put to use. Besides curative treatment, some preventive measures like growing of trees around the monuments have also been recommended¹⁰⁹.

Areas for Future Research

Considering the wide variety of stone types used in the country clearly the conservation work done so far is not adequate and requires extensive researches. Some of these areas could be outlined as follows:

Characterisation of Stone

Since a variety of stones have been used and no two pieces of stones are exactly similar, it is important to prepare a data bank of different types of stone used for historic buildings and sculptures making use of latest techniques of analyses and characterisation. Needless to mention that a wide variety of such techniques are now available. Along with the stone used in the historic buildings and sculptures, it is important to characterise the quarry stone. It will obviate the unnecessary repetition of characterisation work done by different schools of workers from time to time. The presence of such a data bank may also help in determining the mechanism of weathering. Studies should be made to correlate the type of stone with mechanism of weathering so that the studies related to a particular monument could be useful for other monuments made of similar stone.

Standardisation of Description of Decay and Measurement of Its Extent

There is a great need to standardise the various terms being used for describing different types of decay. Efforts are also to be

made to quantify the extent of decay to a reasonable degree of accuracy.

Study of Weathering Mechanism

In order to take appropriate preventive and curative measures, it is important to identify the weathering mechanism. This may be achieved by studying the various weathering products and factors of decay.

Development of Suitable Cleaning Methods and Materials

Cleaning of stone surface is one of the most common treatments required in most of the cases. A variety of methods with or without chemicals have been recommended by conservators. The efficacy of these methods vis-a-vis their cost effectiveness is to be established for Indian monuments and sculptures. The most effective methods need to be standardised so as to get consistent results keeping in mind the ethics and aesthetics of conservation.

Search for a Suitable Consolidant

The different types of decay ultimately lead to loss of material from the body of the stone thus requiring consolidation at one or the other stage. A number of organic and inorganic consolidants have been tested in the developed countries. Some of these products have been claimed to show good results but there is a need to test whether these will behave similarly under altogether different sets of conditions found in the tropical countries like India.

Development of a Suitable Gap Filling Material

Ancient Indian literature suggests the use of a variety of organic additives in lime mortar, which has been used in several of our historic buildings. Theoretically, for restoration and gap filling purposes, it would be better to use the same combination. But since not much information is available regarding the proportion and properties of various additives in the mortar, it is of utmost

importance to develop a suitable gap filling material and test its properties in the laboratory, followed by field trials.

Protection of Surface

Rain and water have a deleterious effect on the stone surface as is evident in many of our monuments. A number of chemical products are available in the market, which are claimed to act as water repellent. It is of therefore paramount importance to test the efficacy of these products in the laboratory.

Eradication of Biological Growth

Biological agencies like moss and algae not only make the surface unsightly, which requires eradication but the growth of higher plants and trees on monuments is a major problem in many cases. The problem becomes acute in case of buildings, which are huge in size and are less frequented by the visitors. A variety of chemicals and methods have been used by workers for their eradication but there is a clear need for standardisation of materials and methods. Development of a suitable biocide, which is harmless to the surface but quite effective in eradicating the growth and keeping it in check for considerable period of time is the need of the hour.

Removal of Birds and Insects

In several unattended historic structures, the inhabitation of pigeons, bats etc., causes great nuisance by way of fouling the atmosphere and soiling the surface through their excreta, which might be harmful to the stone surface. It is important not only to know the harmful effects of these excreta on different types of surfaces, but also to develop suitable methods for repelling these birds from the structures and for cleaning the soiled surface.

The presence of beehives in some monuments is an eye sore. The removal of these bees is not easy. There is a need to develop techniques, which could repel bees from their hives without harming the visitors and the stone. In this respect flavanones

have shown great promise but require further studies before their application on monuments.

Inhibition of Corrosion of Dowels

In many of our monuments, dowels and clamps mainly of iron have been used for anchoring stone slabs. With time, these become corroded and damage the stone. Therefore, it is important to develop techniques for locating these dowels beneath the surface and passivate them *in situ*.

Conclusions

In order to safeguard our rich heritage in stone, it is imperative that a systematic approach to the problem is adopted. This will provide information about the mechanism, methods and materials of treatment. Some information is now available but there are clear gaps in our knowledge, which need to be filled as early as possible. The work requires multi-disciplinary approach.

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